A. FRONT COVER/TITLE PAGE

TITLE OF RESEARCH PROJECT:

ASSESSING THE EFFECTS OF SOIL HUMIC AND FULVIC ACIDS ON GERMINATION AND EARLY GROWTH OF NATIVE AND INTRODUCED GRASS VARIETIES

NAME OF PRINCIPAL INVESTIGATOR: SENESI NICOLA-PROFESSOR

NAME OF CONTRACTOR: UNIVERSITA’ DI BARI

CONTRACT NUMBER: N62558-05-P-0179

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3rd INTERIM REPORT

REPORT PERIOD: MARCH 22, 2006 – SEPTEMBER 22, 2006

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6. AUTHOR(S)

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7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)

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Engineer Research and Development Center , Cold Regions Research & Engineering Laboratory, 72 Lyme Road, Hanover, New Hampshire, 03755-1290, USA.

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12a. DISTRIBUTION/AVAILABILITY STATEMENT

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A

ABSTRACT (Maximum 200 words)

SCIENTIFIC WORK DONE DURING THE REPORTING PERIOD

Chemical and Spectroscopic Characterization of Soil Humic Acids Collected from Greenhouse Pots where the Four Wheatgrass Varieties Were Grown

Experimental

A total of **n. 28 humic acids (HAs)** were extracted by the USDA-St.Paul group using a 0.5 M NaOH solution from duplicate (A, B) or triplicate (A, B, C) samples of the two Wyoming soils, **Guernsey North (GN) and Guernsey South (GS)**, and the one Utah soil, **Dugway (D)**, object of this research, which were collected from **greenhouse pots** where the **four wheatgrass varieties** of interest, the **cv. Pryor** of the **native species Slender (3)** and its **germplasm line SERDP-select (4)** and the **cv. Vavilov** of the **introduced species Siberian (2)** and its **germplasm line SERDP-select (5)**, were separately grown.

All HA samples were characterized by the Bari (this) group for moisture and ash contents, elemental (C, H, N, S, O) and acidic functional group (total acidity, COOH, phenolic OH) composition, and by Fourier transform infrared (FT IR) spectroscopy and fluorescence spectroscopy in the emission, excitation and synchronous scan modes.

RESEARCH PLANS FOR THE REMAINDER OF THE CONTRACT PERIOD

For the remainder of the contract period (8 months) research plans are the following:

(a) Germination and early growth experiments of the three remaining combinations by two of the grass varieties in the presence of the three soil HAs at two concentrations.

(b) Comparison of the germination and seedling growth data with the chemical and spectroscopic parameters of the HAs examined, in order to possibly find out which HA parameters may influence germination and growth of the four grass varieties examined, either singularly or in combination by two.

(c) Possible follow-up experiments with HA concentrations optimal to promote the growth of the grass varieties of interest.

14. SUBJECT TERMS

Navy, Italy, Humic acids, Soils, Greenhouse, Acidic functional group, Wheatgrass, Germination

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B. BODY OF THE REPORT

(1) SCIENTIFIC WORK DONE DURING THE REPORTING PERIOD

1. Chemical and Spectroscopic Characterization of Soil Humic Acids Collected from Greenhouse Pots where the Four Wheatgrass Varieties Were Grown

1.1. Experimental

A total of **n. 28 humic acids (HAs)** were extracted by the USDA-St.Paul group using a 0.5 M NaOH solution from duplicate (A, B) or triplicate (A, B, C) samples of the two Wyoming soils, **Guernsey North (GN) and Guernsey South (GS)**, and the one Utah soil, **Dugway (D)**, object of this research, which were collected from **greenhouse pots** where the **four wheatgrass varieties** of interest, the **cv. Pryor** of the **native species Slender (3)** and its **germplasm line SERDP-select (4)** and the **cv. Vavilov** of the **introduced species Siberian (2)** and its **germplasm line SERDP-select (5)**, were separately grown.
All HA samples were characterized by the Bari (this) group for moisture and ash contents, elemental (C, H, N, S, O) and acidic functional group (total acidity, COOH, phenolic OH) composition, and by Fourier transform infrared (FT IR) spectroscopy and fluorescence spectroscopy in the emission, excitation and synchronous scan modes.

1.2.Results and Discussion

The **elemental composition** (C, H, N, S, O), calculated **atomic ratios** and **acidic functional group** contents, on a moisture- and ash-free basis, **of the n.28 soil HAs** examined are shown in **Tables 1 to 12**, whereas their **FT IR spectra** are shown in **Figs. 1 to 4**, and **fluorescence emission, excitation and synchronous scan spectra** in **Figs. 5 to 16**.
In general, the **elemental and acidic functional group composition** of all HAs studied are typical of soil HAs. With the exception of moisture, ash and acidic functional group contents, very minor differences are shown between duplicates or triplicates of each soil HA analysed. With respect to the corresponding control greenhouse soil HAs (described in the previous second report), the variations in elemental and functional group composition measured as a function of the wheatgrass variety grown, are the following:

(a) where the cv. Vavilov Siberian (2) is grown, the GN2-HAs features higher C, slightly higher N, H and COOH, lower O, O/C ratio and total acidity, and much lower phenolic OH contents; the GS2-HAs shows much higher phenolic OH and total acidity, slightly higher C, N and COOH, and lower S, O and O/C ratio contents; the D2-HAs shows much higher phenolic OH and total acidity contents;
(b) where the cv. Pryor Slender (3) is grown, the GN3-HAs features slightly higher C, N and COOH; slightly lower C/N ratio, lower total acidity, and much lower phenolic OH contents; the GS3-HAs shows much higher phenolic OH, and higher total acidity contents, and slightly lower C/N ratio; the D3-HAs shows slightly higher phenolic OH and total acidity contents;
(c) where the germplasm line SERDP select Slender is grown, the GN4-HAs features slightly lower C/N ratio and COOH content; the GS4-HAs shows much higher phenolic OH, higher total acidity, slightly higher COOH, and lower S contents, the D4-HAs shows slightly higher O and C/N, and slightly lower phenolic OH and total acidity contents;
(d) where the germplasm line SERDP select Siberian is grown, the GN5-HAs features slightly higher C, slightly lower O and S, lower total acidity and much lower phenolic OH contents;

the GS5-HAs shows much higher phenolic OH and total acidity, slightly higher C, and slightly lower O and S contents and O/C ratio; the D5-HAs shows no significant variations.

These results indicate that growing any wheatgrass variety on greenhouse soils affects markedly and differently the phenolic OH and, consequently, the total acidity contents of HAs. The phenolic OH content generally shows a marked decrease for GN-HAs and a marked increase for GS-HAs, whereas for D-HAs the change varies as a function of the wheatgrass variety grown. The COOH and element contents show only minor or no variations as a function of either the soil type or the wheatgrass variety.

The **FT IR spectra** of all HAs examined are typical of soil HAs and generally similar one to another and to the corresponding control soil HAs, featuring absorption bands at similar wavenumber values and relative intensity. The sharp and intense band at about 1100 cm^{-1} present in some control soil HAs and possibly ascribed to Si-O stretching of clay mineral impurities coextracted with the HA, is generally absent in these HAs, possibly due to their low ash content.

The **emission, excitation and synchronous scan fluorescence spectra** of all HAs examined are similar one to another, and typical of soil HAs. With respect to the corresponding control soil HAs, all HAs examined show:

(a) the maximum of the unique broad emission band shifted of about 10-20 nm towards shorter wavelengths;
(b) the main excitation peak shifted slightly (about 5 nm) towards shorter wavelengths, accompanied by two new shoulders at shorter and longer wavelenghts;
(c) similar synchronous scan spectra featuring a unique broad peak at about 480 nm, which is shorter of about 10 nm for GN-HAs and about 25 nm for GS-HAs and D-HAs,

These results suggest a lower humification degree for greenhouse soil HAs from pots where wheatgrass of various varieties were grown, with respect to the corresponding greenhouse control soil HAs.

2. Germination and Early Growth of the wheatgrass varieties grown together in combinations of two

2.1. Experimental

2.1.1. Combinations of wheatgrass varieties

The germination and early growth response of the four varieties of interest were tested in experiments where two varieties were grown together (in combination) each time. The first set of experiments were performed using the following combinations: (a) the **germplasm line SERDP-select** of the **native species Slender wheatgrass** and the **cv. Vavilov** of the **introduced species Siberian wheatgrass (COMBI-A)**; (b) the **germplasm line SERDP-select** of the **native species Slender wheatgrass** and the **germplasm line SERDP-select** of the **introduced Siberian wheatgrass (COMBI-B)**; and (c) the **cv. Vavilov** of the **introduced species Siberian wheatgrass** and the **germplasm line SERDP-select** of the **introduced Siberian wheatgrass (COMBI-C)**.

In order to have comparable results, the germination and early growth of these combinations were studied using the same three HA samples (**GN-HA**, **GS-HA** and **D-HA)** at the same concentrations of 10 and 100 mg/L and in the same conditions used in the previous two sets of experiments performed with the four grasses grown separately and described in the first and second interim reports.

2.1.2. Germination experiment

The seeds were preliminary surface-sterilized by dipping them for 15 min in sodium hypoclorite 0.2 %, and then washing several times with distilled water. Ten (10) seeds of each two-variety combination were placed in the same Petri dish on filter paper, and added with suspensions of each HA at each concentration in distilled water, or with distilled water only (control). In order to allow the free circulation of the germination medium in the dish and, at the same time, keep the seeds of the two varieties separated, a plastic net having small holes was put across the dish. The Petri dishes were kept in the dark for 6 days in a thermostated chamber at a temperature of 20 °C. After this time period, germinated seeds were removed and counted, and the lengths of the primary root and shoot were measured. All the experiments were replicated five (5) times.

2.1.3. Early growth experiment

After the end of the germination experiment and after collection of germination data, the germinated seeds (seedlings) of the two varieties of each combination were inserted into holes of aluminum lids placed on the top of glass pots (3 seedlings of each variety per pot). In order to allow the free circulation of the growth medium in the pot and, at the same time, keep the roots of the two varieties separated, the pot was vertically divided in two parts with a plastic net having small holes. The pots were filled with the Nitch nutrient solution, in the absence (control) or presence of each HA at concentrations of 10 and 100 mg/L. The pH of the nutrient solution was preliminary adjusted to 6.5 with a solution of NH_4OH. Blanks (without seedlings) were also prepared for each treatment in order to measure the pH change during the growth period in the absence of plants. The pH of all treatment media ranged between 6.5 (control) and 5.9 (GS-HA at 100 mg/L). The pots were then placed in a Phytotron growth chamber, and seedlings were allowed to grow for a period of 21 days in the following conditions: (a) photoperiod of 12-h; (b) temperature of 20 °C and humidity of 74% during the illumination period; and (c) temperature of 17 °C and humidity of 70% during the dark period. At the end of the experiment, the pH of the growth solutions and blanks, and the length and fresh and dry weights (60 °C for 48 h) of roots and shoots were measured. All experiments were conducted in five replicates.

2.1.4. Statistical analyses

All germination and growth data were analyzed statistically by one-way analysis of variance (ANOVA) and the means of the treatments were separated by the least significant difference (LSD) test.

2.2. Results and Discussion

2.2.1. Germination data

Statistical treatment of data by ANOVA shows, with respect to the corresponding controls, and as a function of either the HA type or HA concentration, the existence of: (a) a significant difference only in the case of primary root and shoot lengths of cv. Vavilov Siberian in **COMBI-A (Table 13)**; (b) a significant and highly significant difference, respectively, in the germination and primary root length of SERDP-select Siberian in **COMBI-B (Table 14)**; (c) a significant or highly significant difference in the germination of SERDP-select Siberian and primary root length for both varieties in **COMBI-C (Table 15)**. No significant effects are measured in the other cases.

COMBI-A

Numerical data in **Table 16** show that no HA treatment influences statistically the germination % of either varieties. However, data in **Fig. 17** (top) show that, both in the absence (control) and in the presence of any HA at any concentration the germination % of SERDP-select Slender is greater than that of cv. Vavilov Siberian, especially in the presence of D-HA and GN-HA at 100 mg/L.
Numerical data in **Table 19** show that, with respect to the control, only D-HA at 100 mg/L increases significantly the primary root and shoot lengths of cv. Vavilov Siberian. Further, data in **Fig. 18** (top) show that both in the control and, especially, in the presence of D-HA at 100 mg/L, GN-HA at 10 mg/L and GS-HA at either 10 or 100 mg/L, the primary shoot and root lenghts of the cv. Vavilov Siberian are greater than those of the SERDP-select Slender.

COMBI-B

Numerical data in **Table 17** indicate that, with the only exception of GS-HA at 10 mg/L, which promotes the germination of SERDP-select Siberian, no other treatment exerts a statistically significant influence on the germination of either varieties. Further, data in **Fig. 17** (middle) show that in the presence of GS-HA at 100 mg/L, especially, and D-HA at 10 mg/L the germination of SERDP-select Siberian is favored with respect to that of the other variety, SERDP-select Slender, whereas the opposite occurs in the absence of HA (control) and, secondarily, in the presence of GS-HA at 10 mg/L and GN-HA at both concentrations.
All HA treatments, with the only exception of GN-HA at 100 mg/L, increase significantly the primary root length of SERDP-select Siberian **(Table 20)**, with respect to the control, whereas no significant effects are measured for primary shoot length of this variety and for both primary root and shoot lengths of the other variety, SERDP-select Slender. However, data in **Fig. 18** (middle) show that in most cases, and especially in the presence of GS-HA and GN-HA at 10 mg/L, SERDP-select Siberian features primary root and shoot lengths greater than those of SERDP-select Slender. The only exceptions where the opposite occurs are represented by the control for primary root, especially, and GN-HA at 100 mg/L.

COMBI-C

Numerical data in **Table 18** indicate that D-HA and GN-HA at 100 mg/L and GS-HA at both concentrations influence significantly the germination of SERDP-select Siberian, whereas no statistically relevant effects are measured in the other cases. Data in **Fig. 17** (bottom) show that in the presence of any HA at any concentration, and especially D-HA at 100 mg/L and GS-HA at both concentrations, the germination of the SERDP-select Siberian variety is promoted with respect to that of the cv. Vavilov Siberian. Only in the absence of HA (control) the opposite occurs.
Generally, with respect to the control, the presence of any HA at any concentration increases significantly or highly significantly the primary root length of both varieties, whereas no effect is shown in any case for shoot length **(Table 21)**. Data in **Fig. 18** generally indicate that primary root length of cv. Vavilov Siberian is greater than that of SERDP-select Siberian, with the exception of germination in the presence of D-HA at 100 mg/L and GS-HA at 10 mg/L, whereas the opposite occurs for shoot length, with the exception of germination in the presence of GS-HA and GN-HA at 100 mg/l.

2.2.2. pH of the growth medium

Statistical treatment of data by one-way analysis of variance shows that, with respect to the corresponding controls, the pH of the medium is affected highly significantly during the 21-day growth period of seedlings in any combination and any HA treatment **(Tables 13-15)**. Only slight pH variations occur for the blanks (no plants present) during the same period of time, whereas a

general acidification of the growth medium is observed in all the three combinations either in the control treatments or in any HA at any concentration **(Table 22)**.

2.2.3. Early growth data

Statistical treatment of data by one-way analysis of variance shows, with respect to the corresponding controls, and as a function of either the HA type or HA concentration, the existence of: (a) significant or highly significant differences for all parameters, except root dry weight, of both varieties in **COMBI-A (Table 13)**; (b) highly significant differences for root fresh weights of SERDP-select Slender, and shoot fresh and dry weights of both varieties in **COMBI-B (Table 14)**; (c) significant or highly significant differences for all parameters, except root length, of both varieties in **COMBI-C (Table 15)**.

COMBI-A

Numerical data in **Tables 23, 26 and 29** indicate that almost all HA treatments depress significantly or highly significantly root and, especially, shoot growth of SERDP-select Slender, with respect to the control. Similar effects, even if less pronounced and mainly on shoot, are measured for the variety grown in combination, i.e. the cv. Vavilov Siberian.
Further, data in **Figs. 19-21** show that both in the absence (control) and in the presence of any HA at any concentration the differences in root growth between the two varietie are generally greater than those in shoot growth. In particular, root length and shoot dry weight of SERDP-select Slender are greater than those of cv. Vavilov Siberian, whereas the opposite generally occurs for shoot length and fresh weight and root fresh and dry weights.

COMBI-B

Numerical data in **Tables 24, 27, and 30** indicate that, with respect to the control, no HA treatment has a significant influence on root and shoot length of both varieties, whereas, different from the previous combination, HA treatments generally cause an increase, even if not always statistically significant, of root and shoot fresh weights and shoot dry weight of both varieties, especially at the higher dose.
Further, data in **Figs. 19-21** show that both in the absence (control) and in the presence of any HA at any concentration root length of SERDP-select Slender are greater than that of SERDP-select Siberian, whereas the opposite generally occurs for all other parameters measured. Apparently, the SERDP-select Siberian generally predominates in the competition with SERDP-select Slender.

COMBI-C

Numerical data in **Tables 25, 28 and 31** show that, with respect to the control, HA treatments generally enhance shoot length and, similar to results obtained for COMBI-B, root and shoot fresh and dry weights of both varieties, even if in some cases the increase is statistically not significant.
Further, data in **Figs. 19-21** show that, with some exceptions in root length, all other parameters measured for any HA treatment indicate a net predominance of SERDP-select Siberian growth over the variety in combination, i.e. the cv. Vavilov Siberian.

2.3. Concluding comments

Although the **germination and primary root and shoot growth** of the wheatgrass varieties in the three combinations examined are affected in different ways and at different extent by the HA origin and concentration, some general effects can be observed: (a) any HA at any concentration stimulates significantly or highly significantly the germination and/or primary root elongation of SERDP-select Siberian in COMBI-C and COMBI-B, and primary root elongation of cv. Vavilov Siberian in COMBI-C; (b) the apparent positive effect of HA in promoting the germination and/or primary root and shoot growth of one variety with respect to the other in any combination is variable in almost all cases examined; (c) the germplasm line SERDP-select of Slender wheatgrass shows a higher germination % both in the absence (control) and in the presence of any HA at any concentration, with respect to the cv. Vavilov Siberian, and in some cases with respect to the SERDP-select Siberian variety, whereas both Siberian varieties feature primary root and shoot lengths greater than those of the SERDP-select Slender; (d) the germplasm line SERDP-select of Siberian wheatgrass in any HA treatment features a higher germination % than the corresponding cv. Vavilov, whereas the opposite occurs in absence of HA (control), and shoot and root lengths are affected variously for the two varieties in combination.
In general, the **early growth** parameters of the wheatgrass varieties grown in three combinations of two show more definite trends than the corresponding germination and seedling parameters discussed above. In particular: (a) almost all HA treatments depress the growth of both varieties in COMBI-A, whereas the growth, especially the weights, of both varieties is enhanced in COMBI-B and, especially, in COMBI-C; (b) the maximum positive effect of HAs is observed for shoot elongation of SERDP-select Siberian in COMBI-C; (c) comparing the growth of the two varieties in COMBI-A, the differences in parameters measured do not show a clear prevalence of one variety over the other, whereas in COMBI-B and COMBI-C, with the exception of root length, a clear prevalence is apparent for SERDP-select Siberian over SERDP-select Slender and cv. Vavilov Siberian; (d) the highest root elongation, averaged among treatments, is generally observed for SERDP-select Slender in COMBI-B, and the highest root and shoot fresh and dry weights are measured for SERDP-select Siberian in COMBI-B and COMBI-C.

(2) RESEARCH PLANS FOR THE REMAINDER OF THE CONTRACT PERIOD

For the remainder of the contract period (8 months) research plans are the following:

(a) Germination and early growth experiments of the three remaining combinations by two of the grass varieties in the presence of the three soil HAs at two concentrations.
(b) Comparison of the germination and seedling growth data with the chemical and spectroscopic parameters of the HAs examined, in order to possibly find out which HA parameters may influence germination and growth of the four grass varieties examined, either singularly or in combination by two.
(c) Possible follow-up experiments with HA concentrations optimal to promote the growth of the grass varieties of interest.

(3) SIGNIFICANT ADMINISTRATIVE ACTIONS DURING THE PERIOD REPORTED: NONE.

(4) ANY OTHER INFORMATION : NONE.

(5) ANNEX: TABLES 1 TO 31 AND FIGURES 1 TO 21.

(A) AMOUNT OF UNUSED FUNDS REMAINING ON THE CONTRACT AT THE END OF THE PERIOD COVERED BY THE REPORT: US$ 10,000.

(B) IMPORTANT PROPERTIES ACQUIRED WITH CONTRACT DURING THIS PERIOD: NONE.
(C) METHOD OF REPRODUCTION: E-MAIL ATTACHMENTS, PHOTOCOPYING.

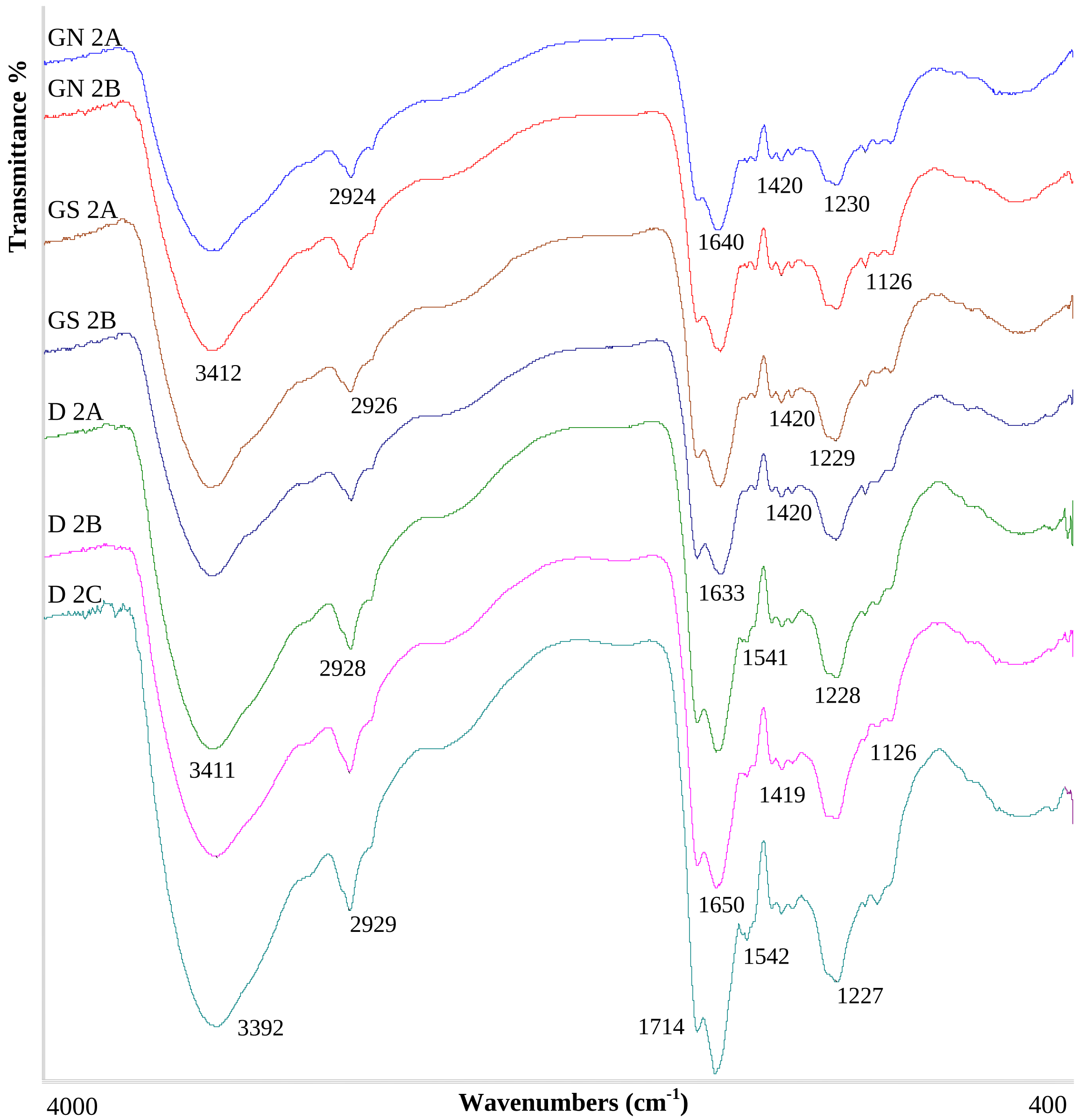

Figure 1. FT IR spectra of humic acids extracted with 0.5 M NaOH from greenhouse soils where the **cv. Vavilov Siberian** wheatgrass was grown.

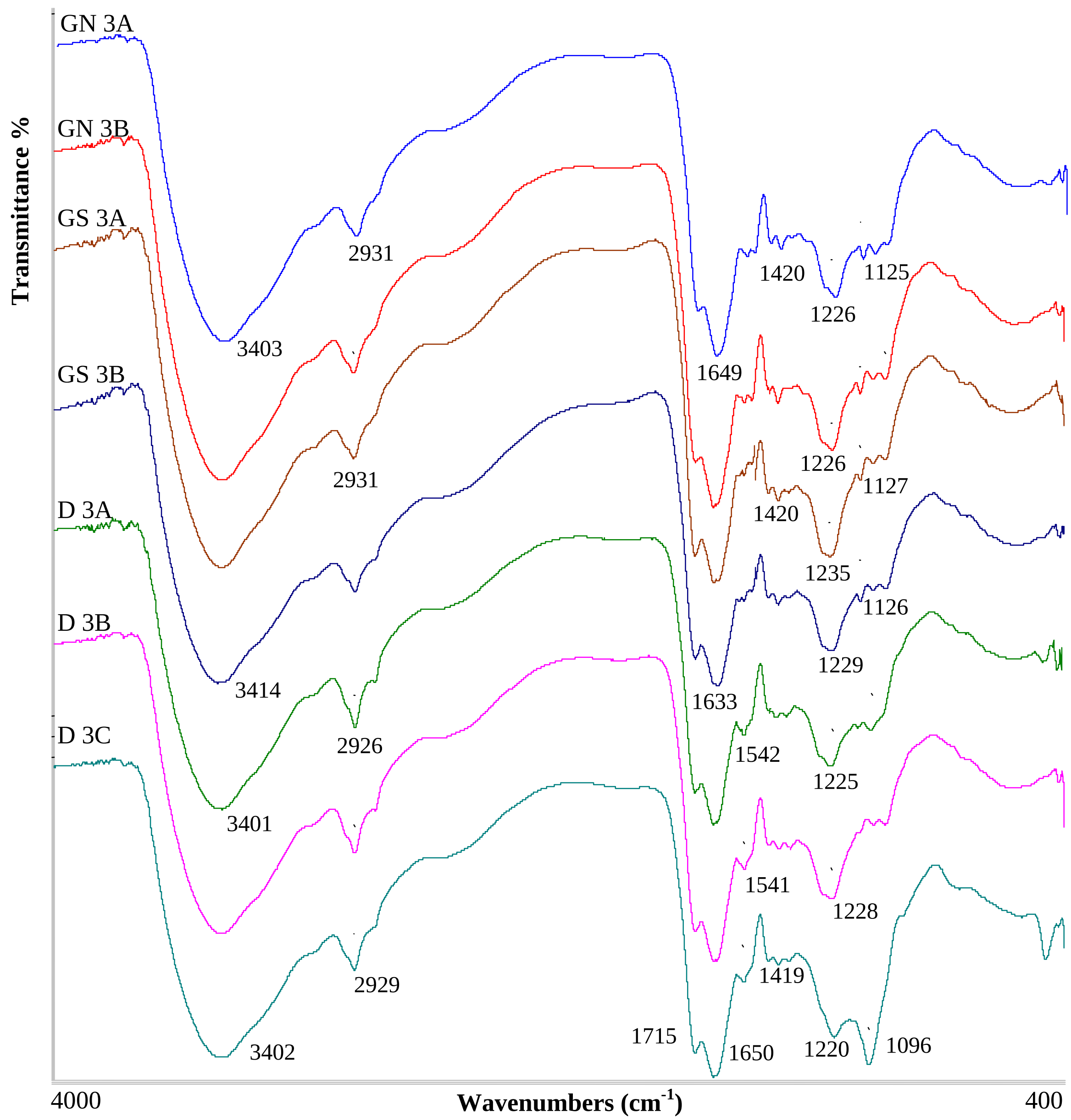

Figure 2. FT IR spectra of the humic acids extracted with 0.5 M NaOH from greenhouse soils where the **cv. Pryor Slender** wheatgrass was grown.

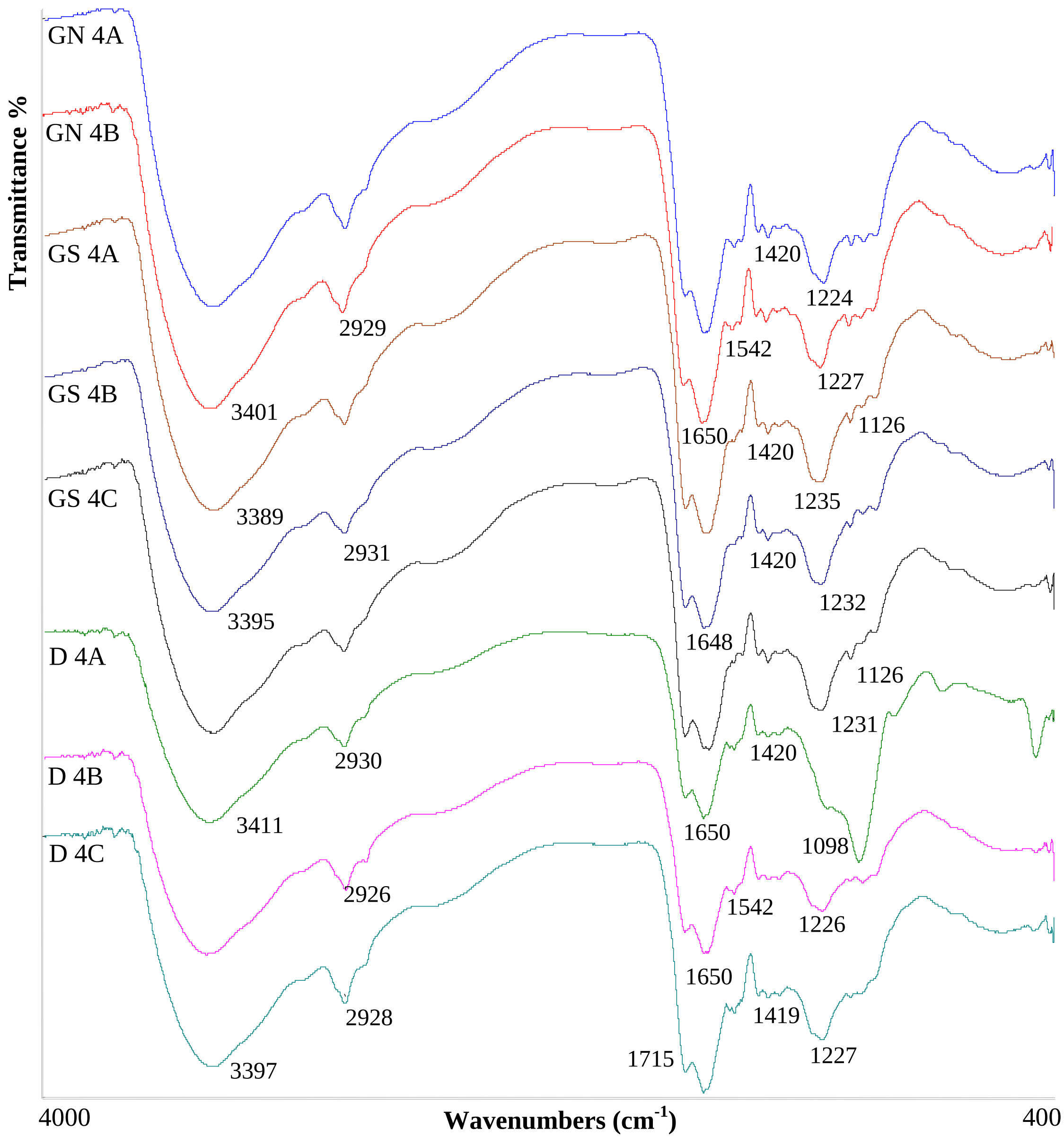

Figure 3. FT IR spectra of the humic acids extracted with 0.5 M NaOH from greenhouse soils where the germplasm line **SERDP-select of Slender** wheatgrass was grown.

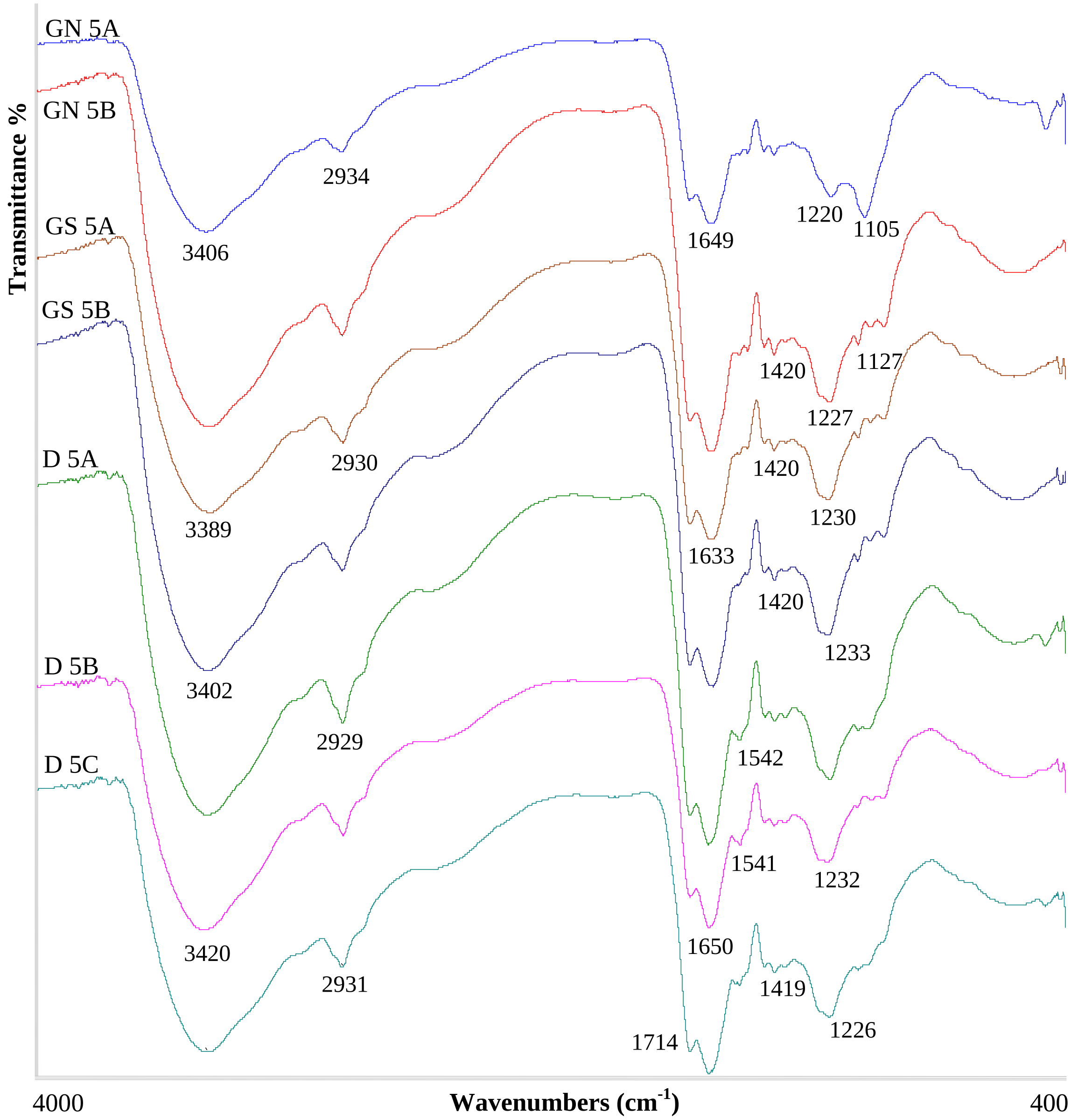

Figure 4, FT IR spectra of the humic acids extracted with 0.5 M NaOH from greenhouse soils where the germplasm line **SERDP-select of Siberian** wheatgrass was grown.

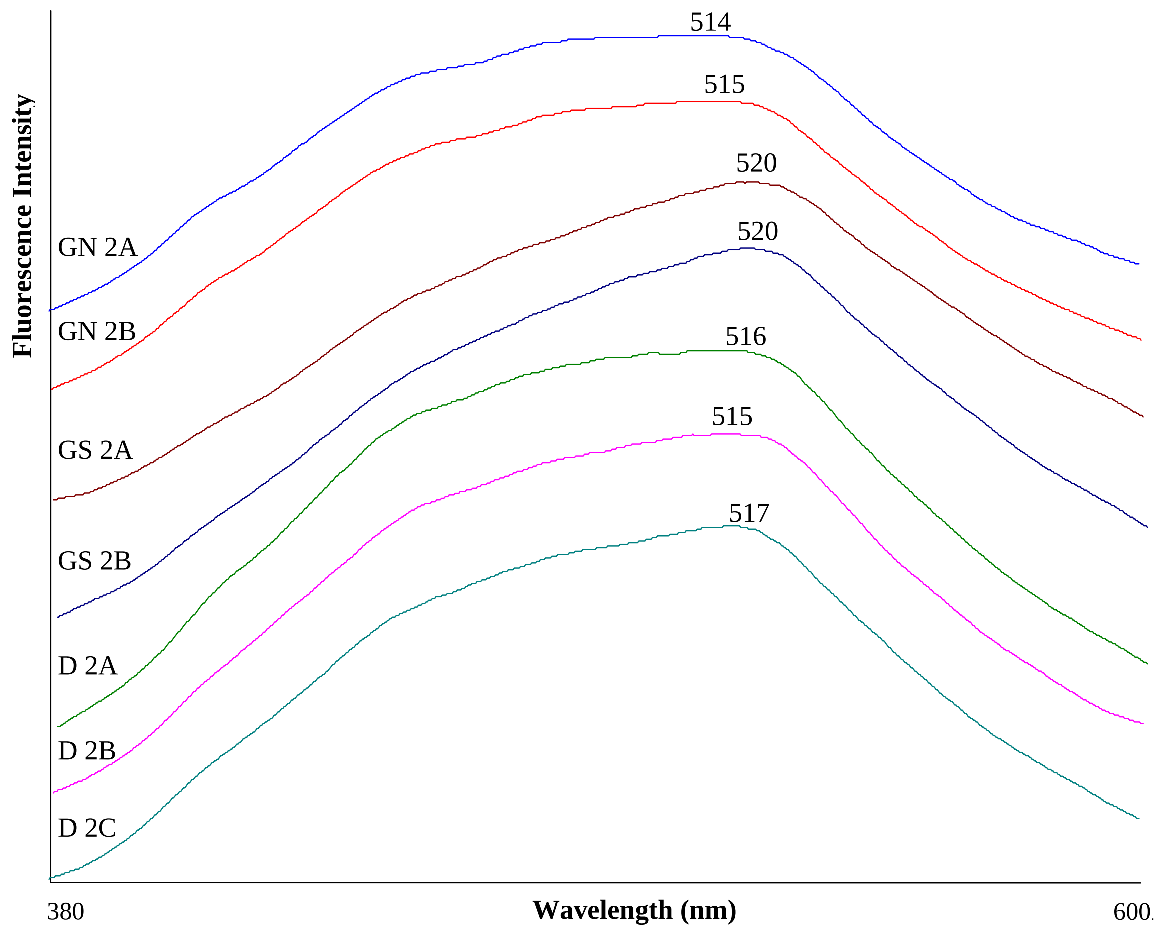

Figure 5. Emission fluorescence spectra of humic acids extracted with 0.5 M NaOH from greenhouse soils where the **cv. Vavilov Siberian** wheatgrass was grown.

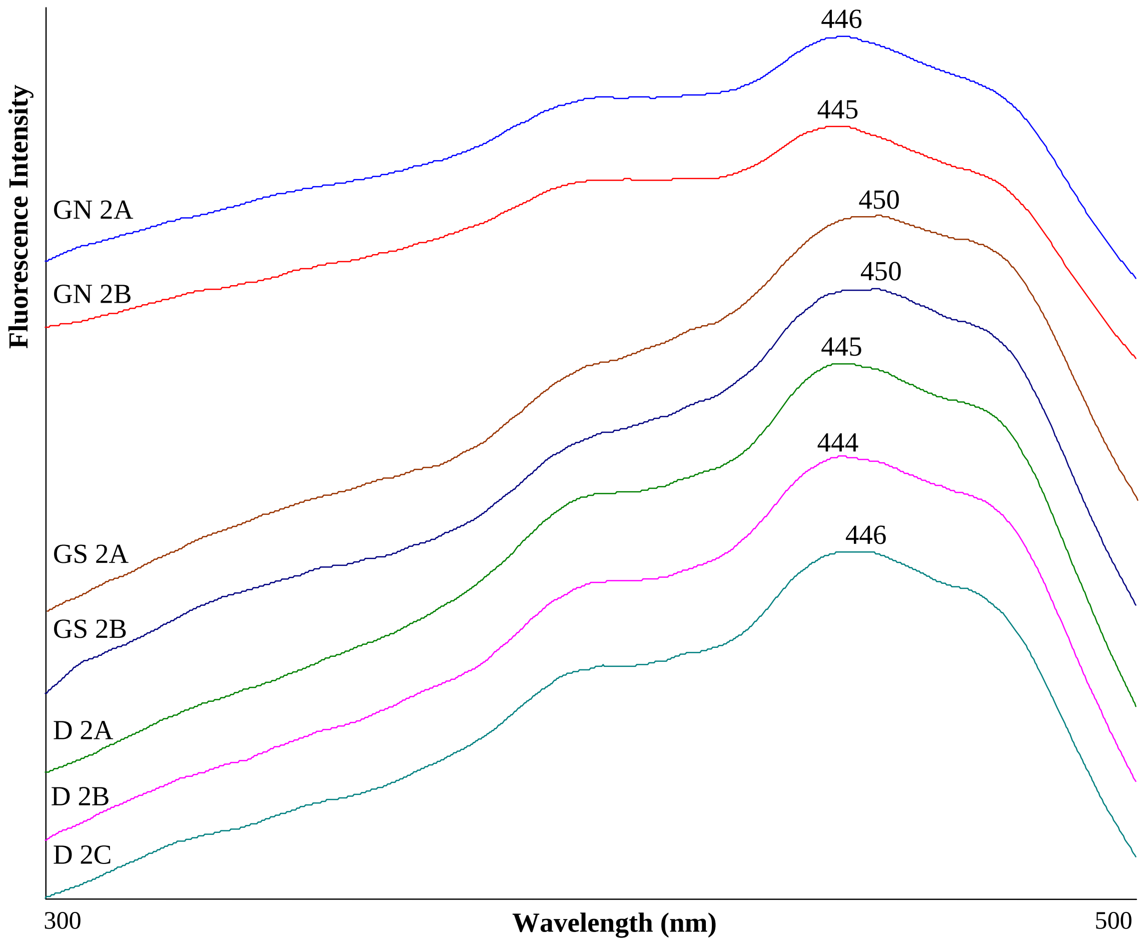

Figure 6. Excitation fluorescence spectra of humic acids extracted with 0.5 M NaOH from greenhouse soils where the **cv. Vavilov Siberian** wheatgrass was grown.

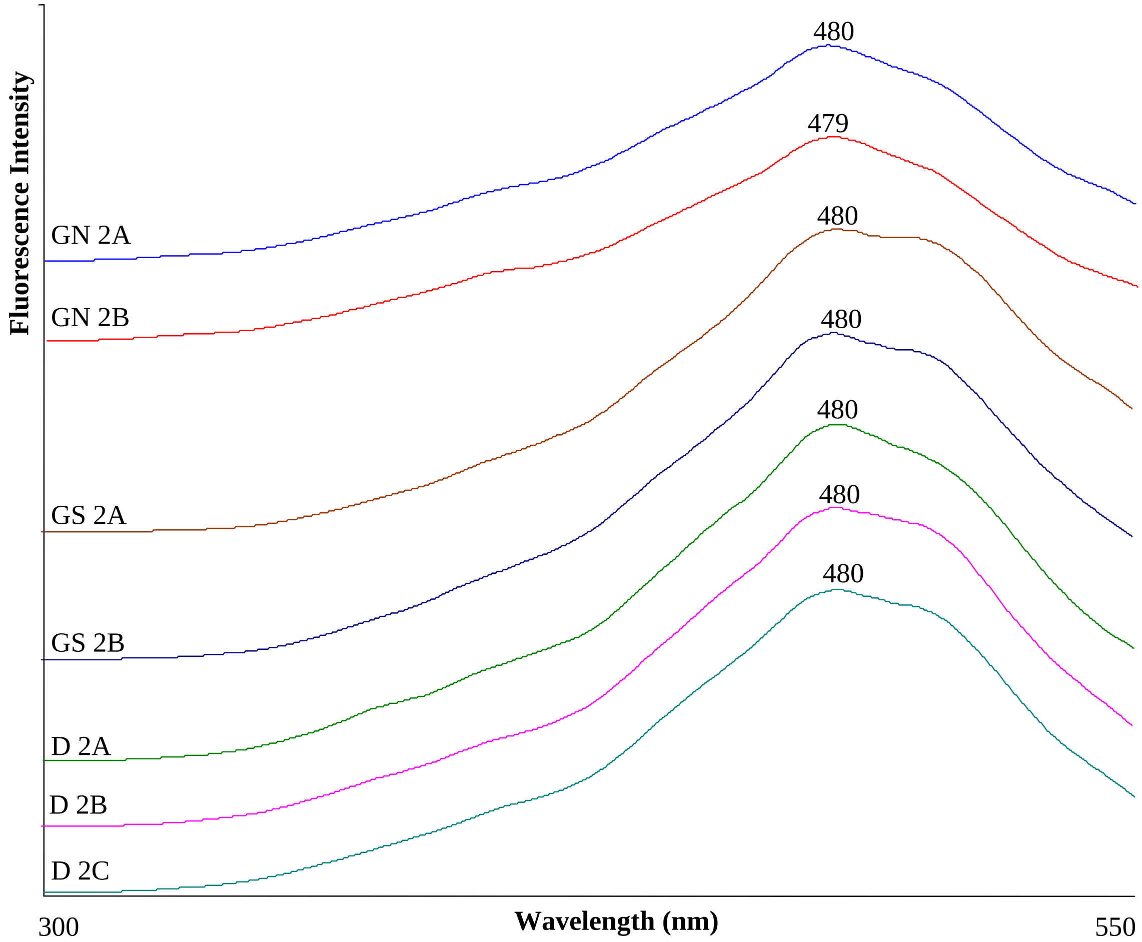

Figure 7. Synchronous scan fluorescence spectra of humic acids extracted with 0.5 M NaOH from greenhouse soils where the **cv. Vavilov Siberian** wheatgrass was grown.

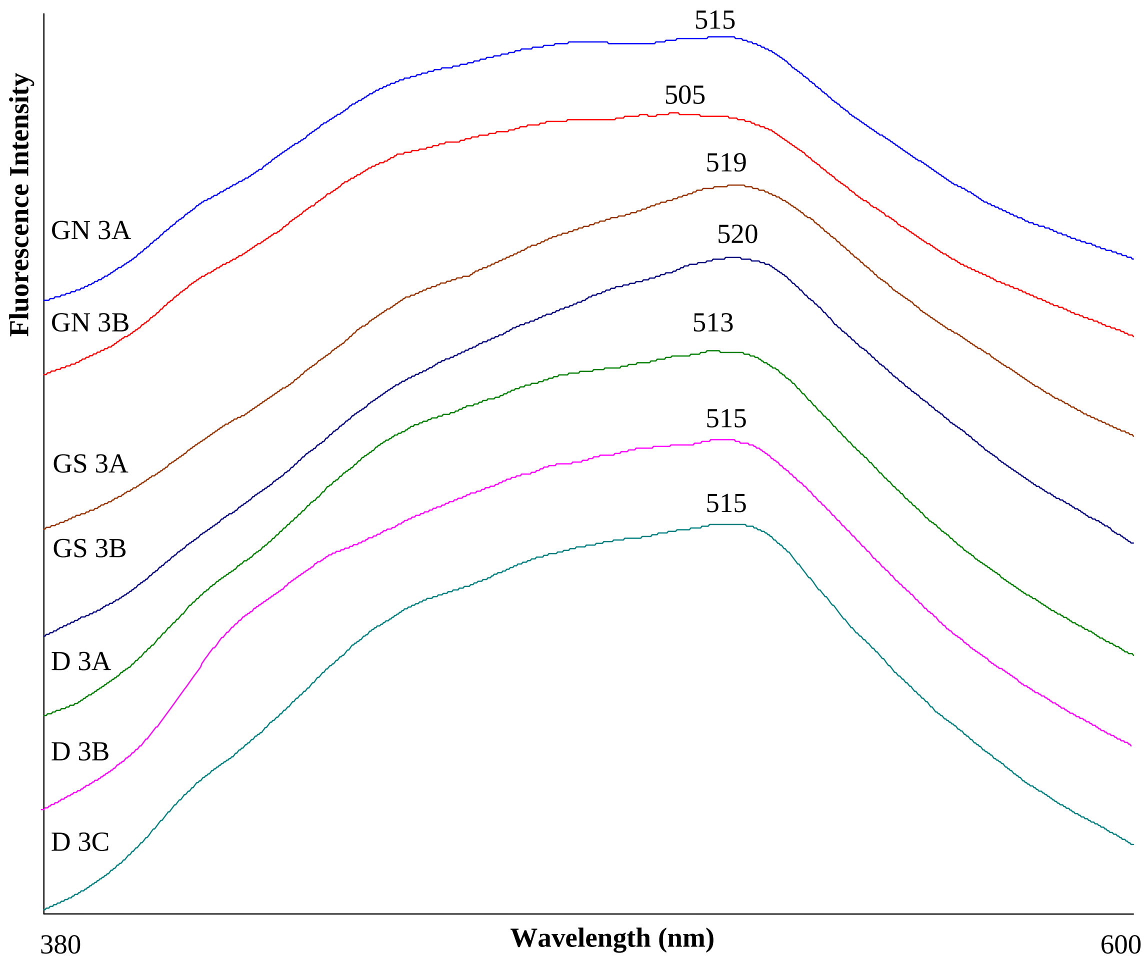

Figure 8. Emission fluorescence spectra of the humic acids extracted with 0.5 M NaOH from greenhouse soils where the **cv. Pryor Slender** wheatgrass was grown.

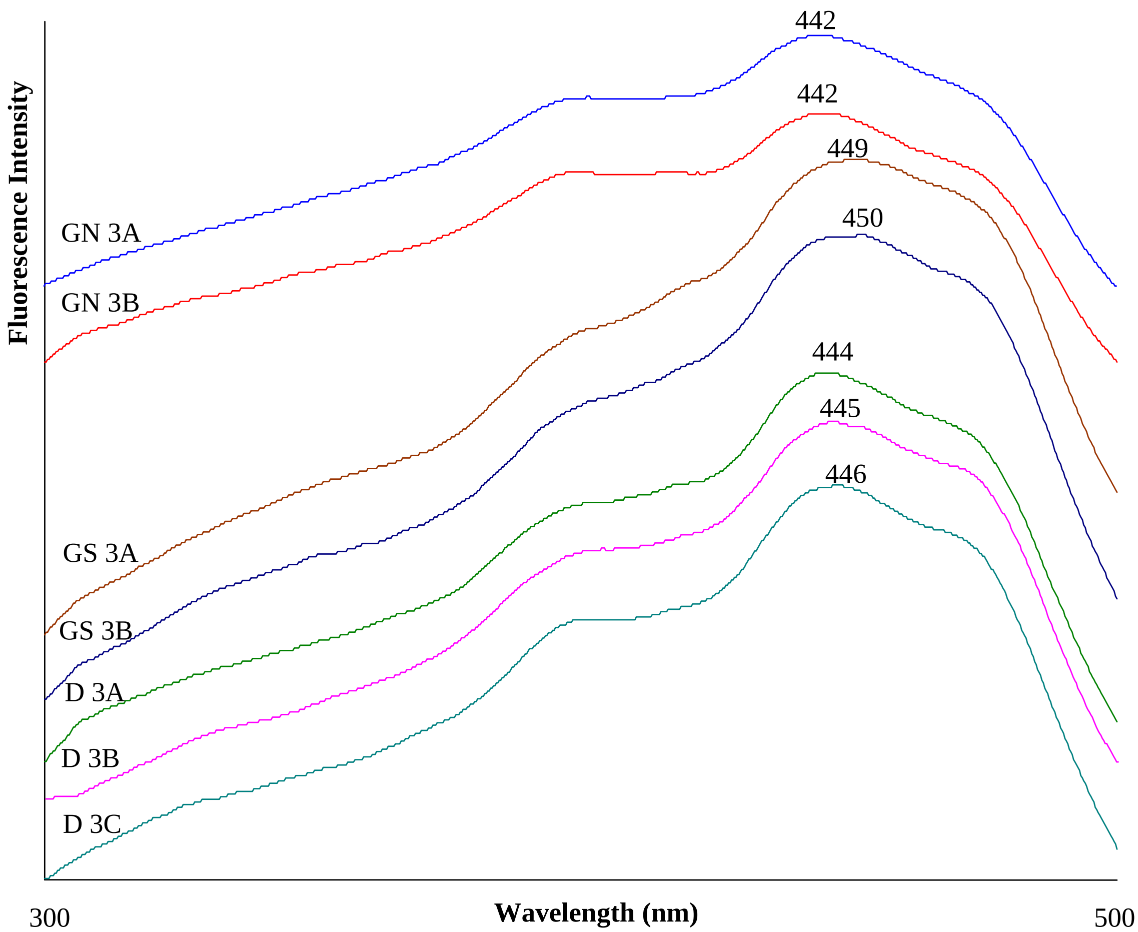

Figure 9. Excitation fluoscence spectra of the humic acids extracted with 0.5 M NaOH from greenhouse soils where the **cv. Pryor Slender** wheatgrass was grown.

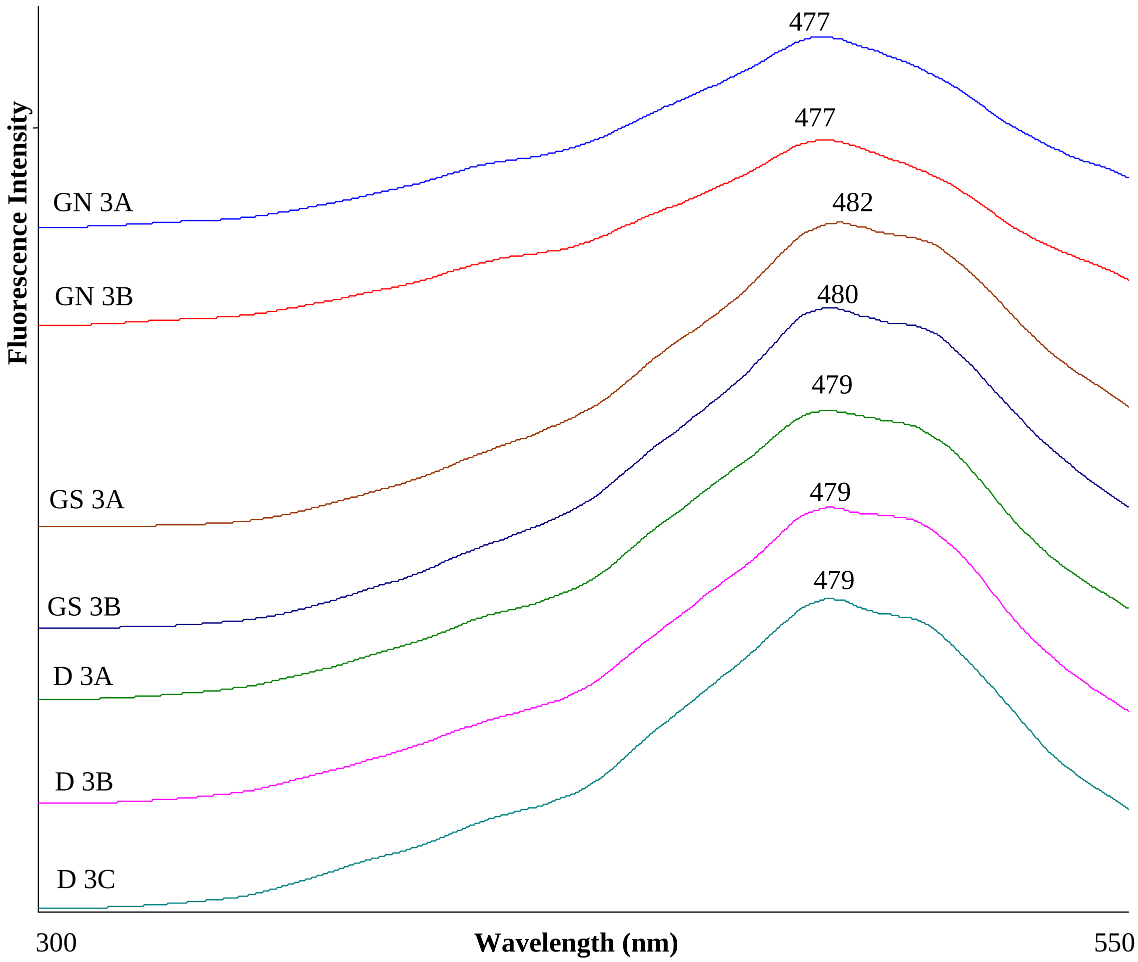

Figure 10. Synchronous scan fluoscence spectra of the humic acids extracted with 0.5 M NaOH from greenhouse soils where the **cv. Pryor Slender** wheatgrass was grown.

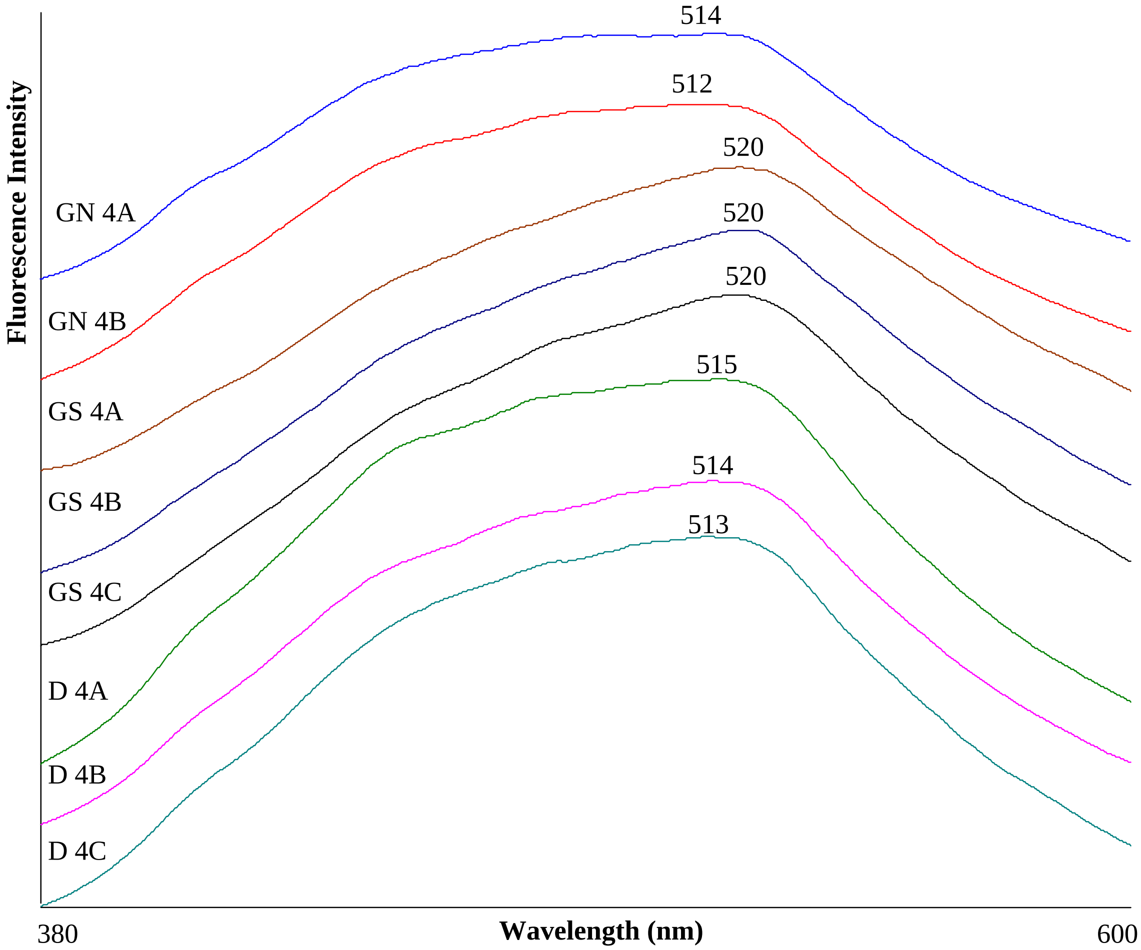

Figure 11. Emission fluorescence spectra of the humic acids extracted with 0.5 M NaOH from greenhouse soils where the germplasm line **SERDP-select of Slender** wheatgrass was grown.

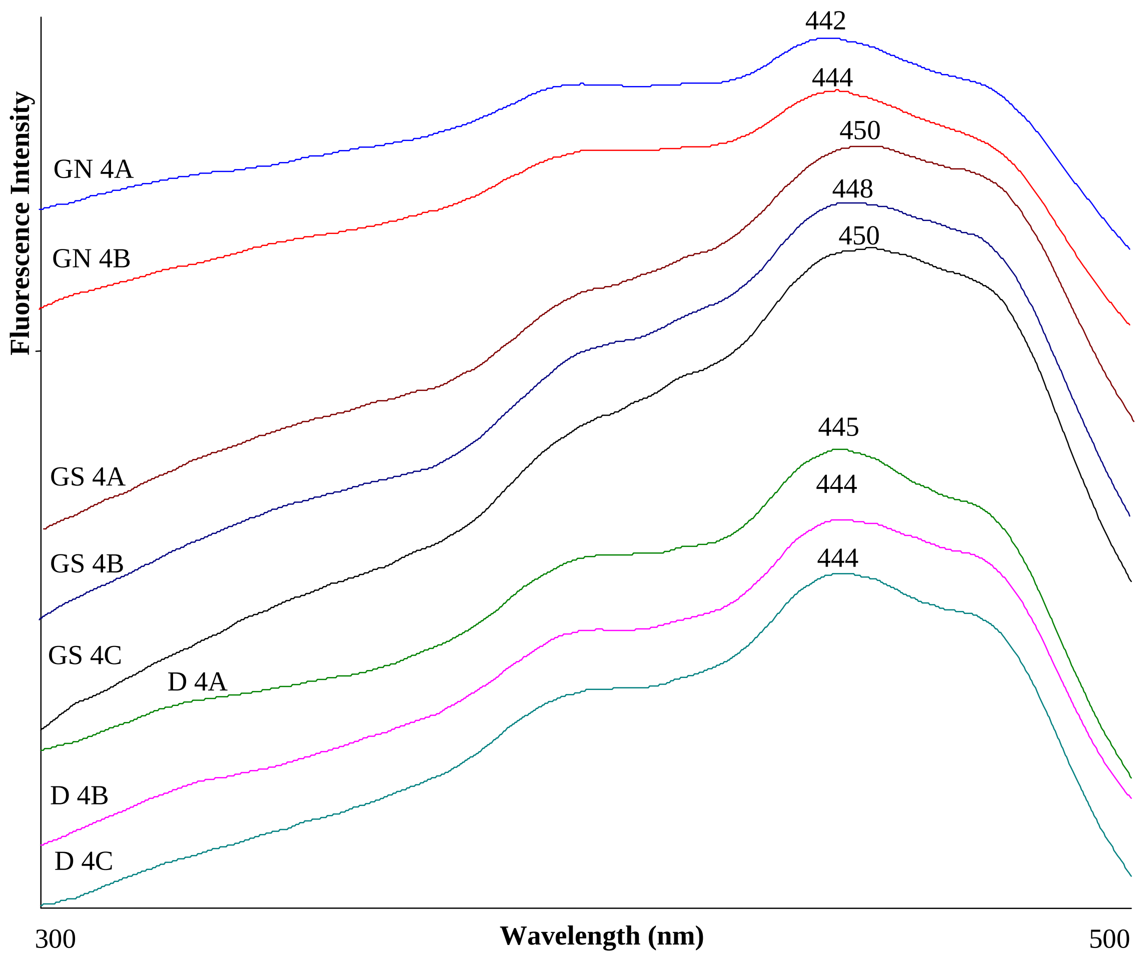

Figure 12. Excitation fluorescence spectra of the humic acids extracted with 0.5 M NaOH from greenhouse soils where the germplasm line **SERDP-select of Slender** wheatgrass was grown.

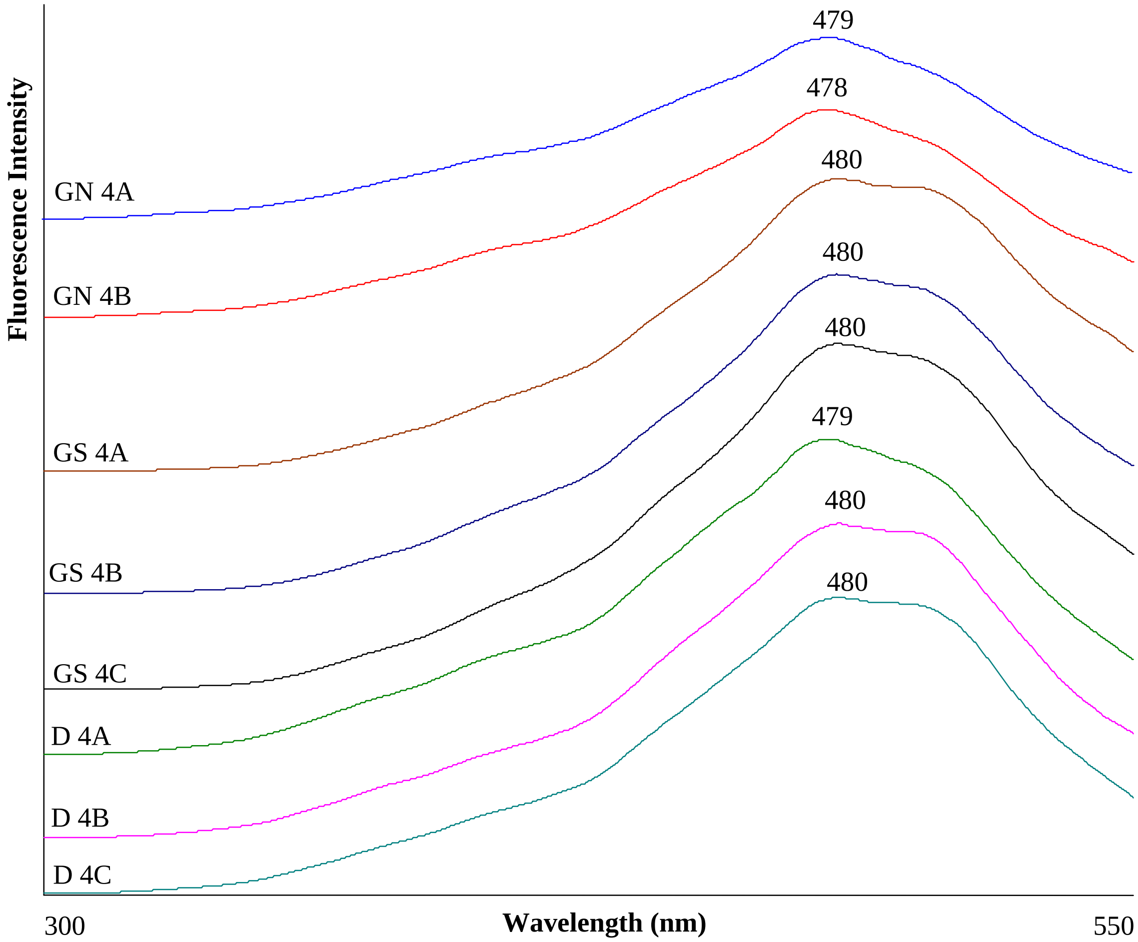

Figure 13. Synchronous scan fluorescence spectra of the humic acids extracted with 0.5 M NaOH from greenhouse soils where the germplasm line **SERDP-select of Slender** wheatgrass was grown.

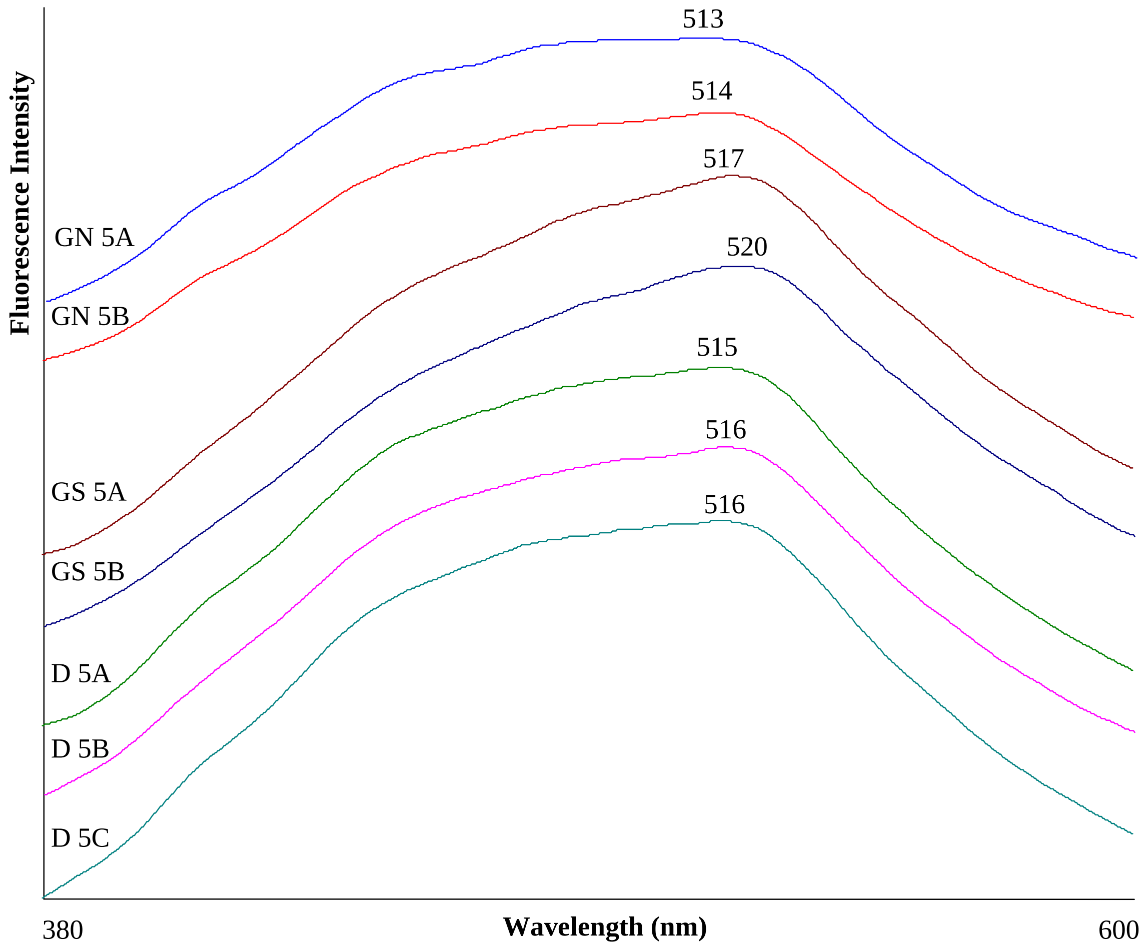

Figure 14. Emission fluorescence spectra of the humic acids extracted with 0.5 M NaOH from greenhouse soils where the germplasm line **SERDP-select of Siberian** wheatgrass was grown.

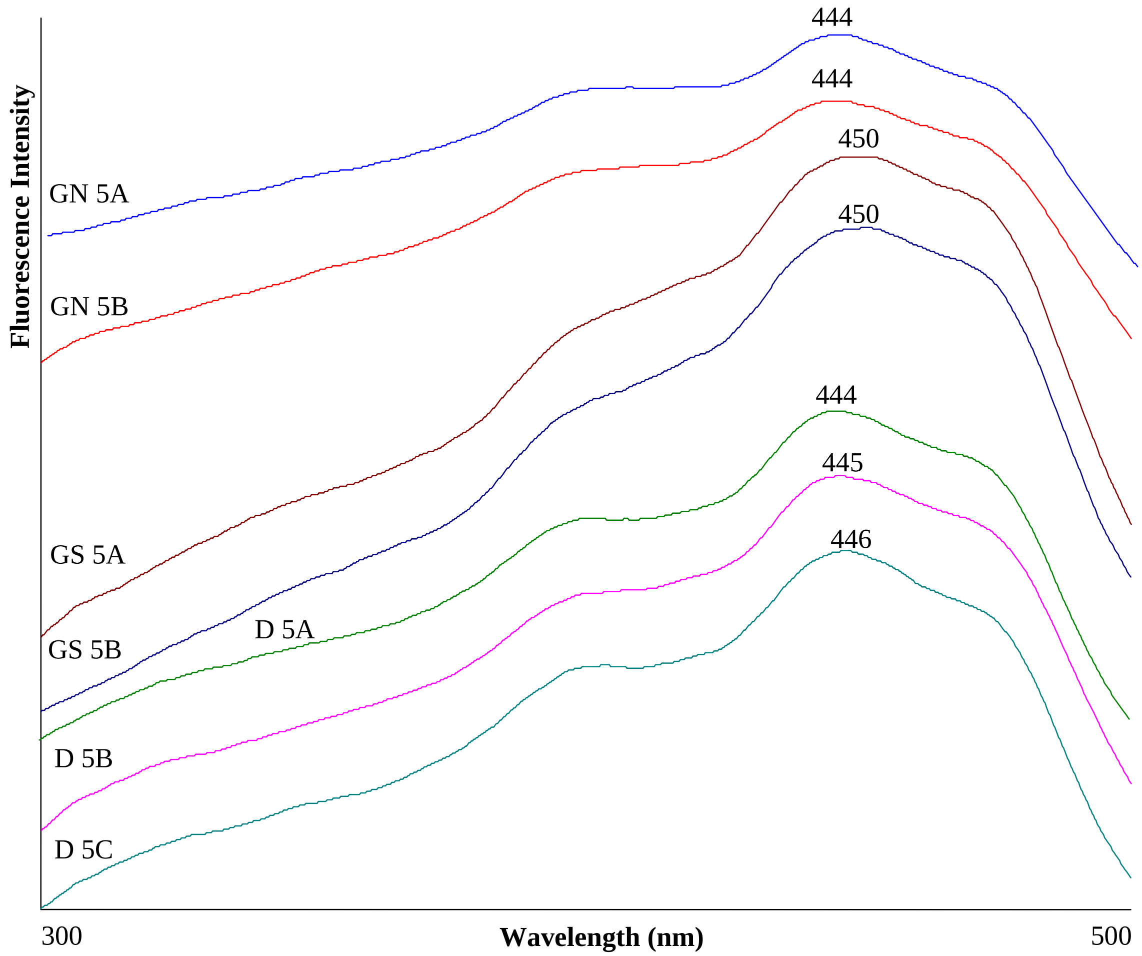

Figure 15. Excitation fluorescence spectra of the humic acids extracted with 0.5 M NaOH from greenhouse soils where the germplasm line **SERDP-select of Siberian** wheatgrass was grown.

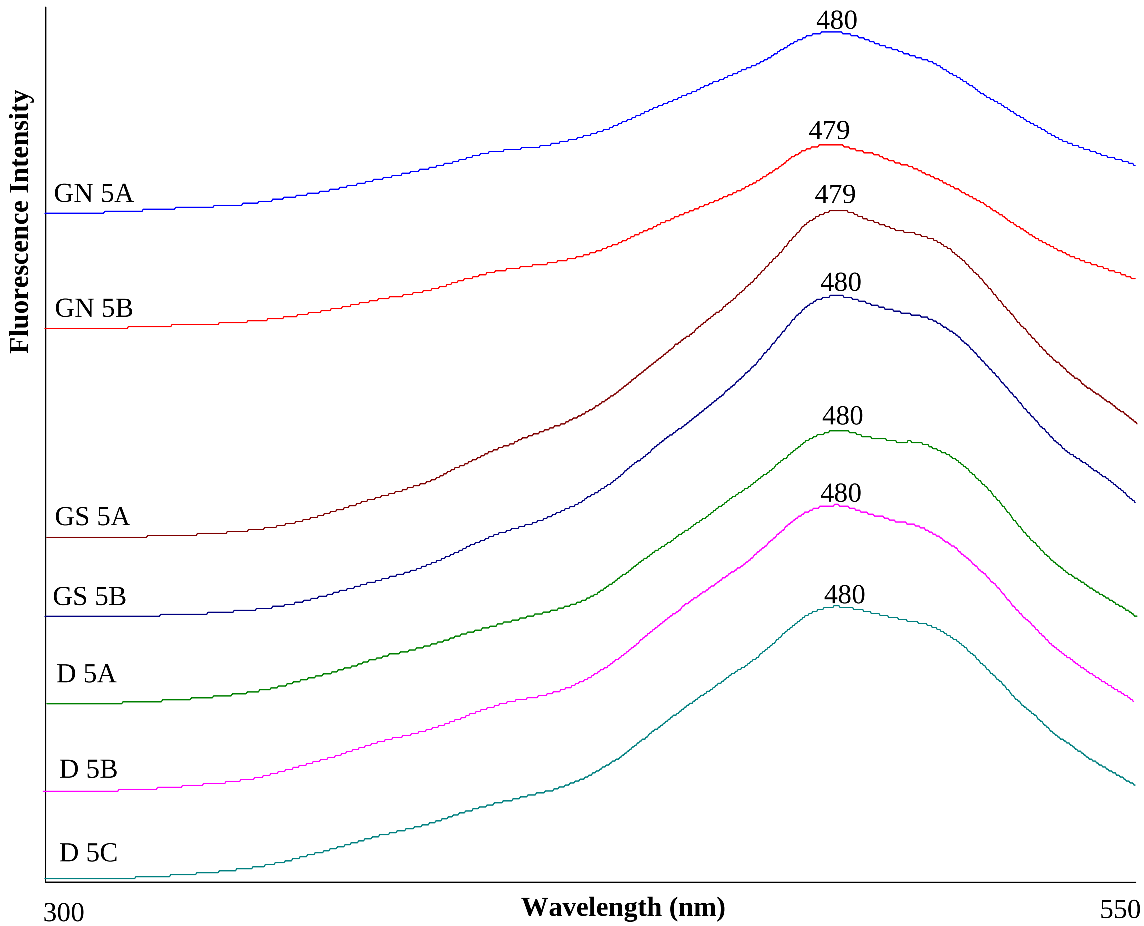

Figure 16. Synchronous scan fluorescence spectra of the humic acids extracted with 0.5 M NaOH from greenhouse soils where the germplasm line **SERDP-select of Siberian** wheatgrass was grown.

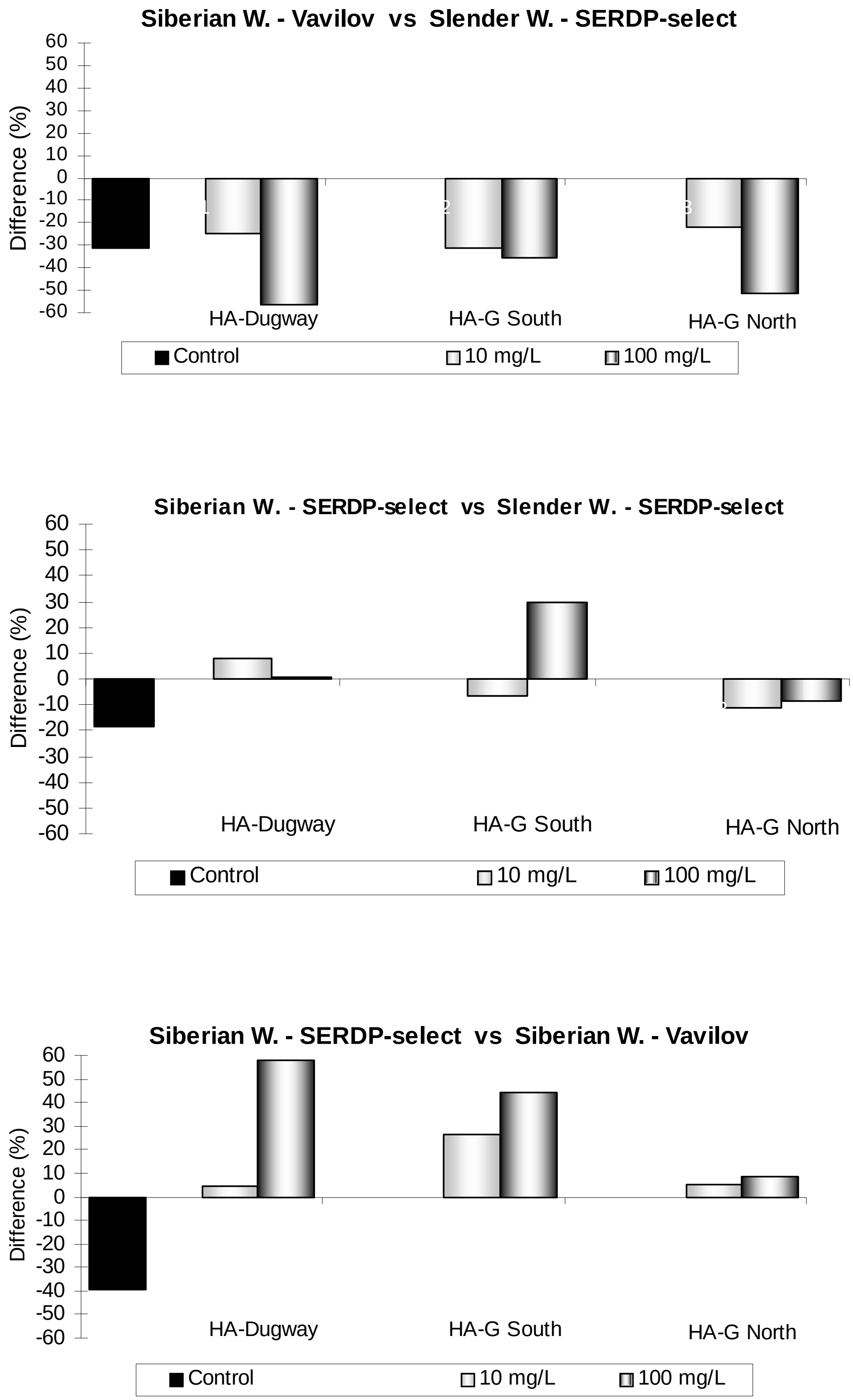

Figure 17. Effect of HAs at different concentrations on the difference (%) of number of germinated seeds between the two varieties grown together. Top, COMBI-A, middle, COMBI-B, bottom, COMBI-C.

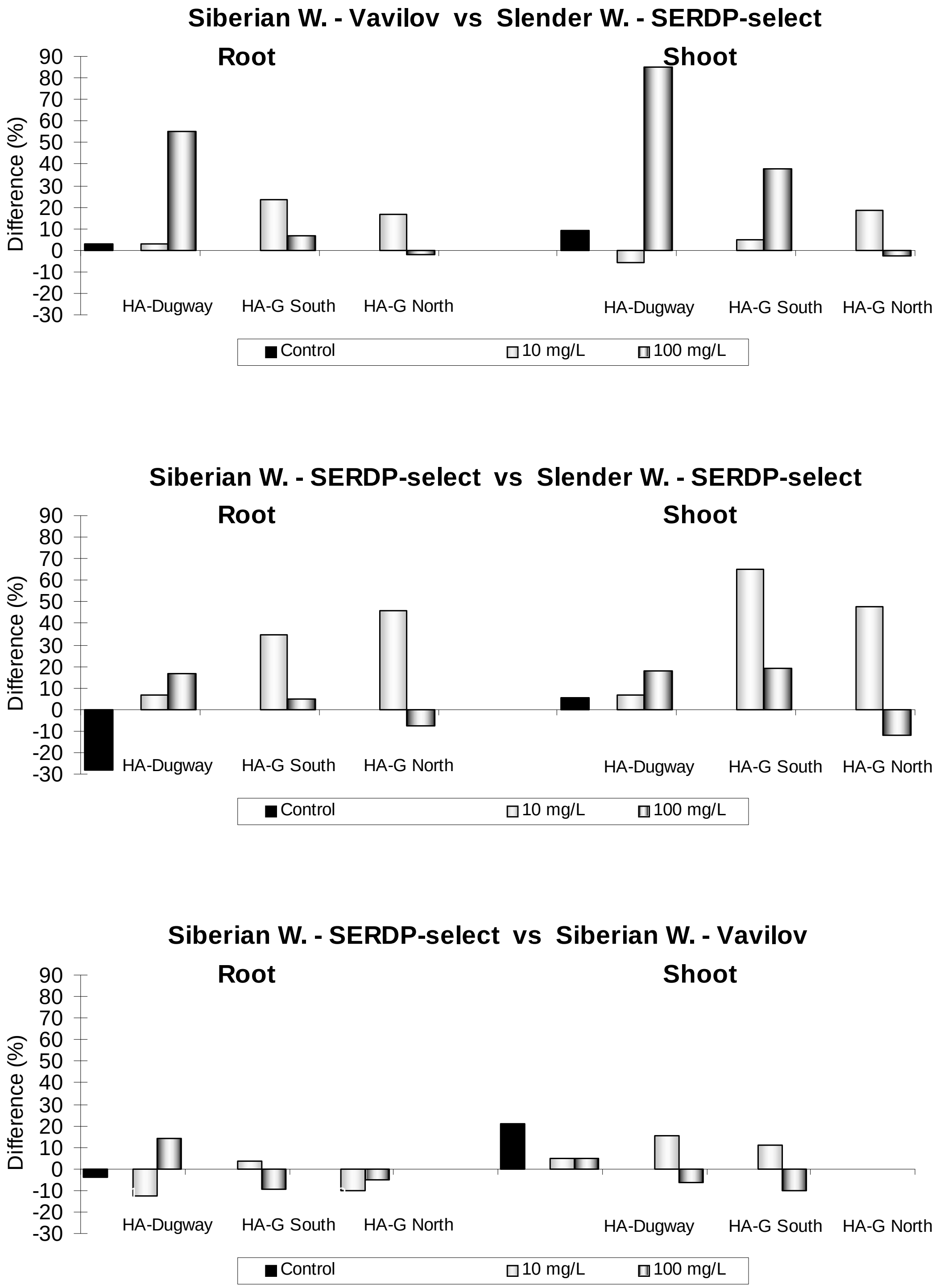

Figure 18. Effect of HAs at different concentrations on the difference (%) of primary shoot and root length of germinated seeds between the two varieties grown together. Top, COMBI-A, middle, COMBI-B, bottom, COMBI-C.

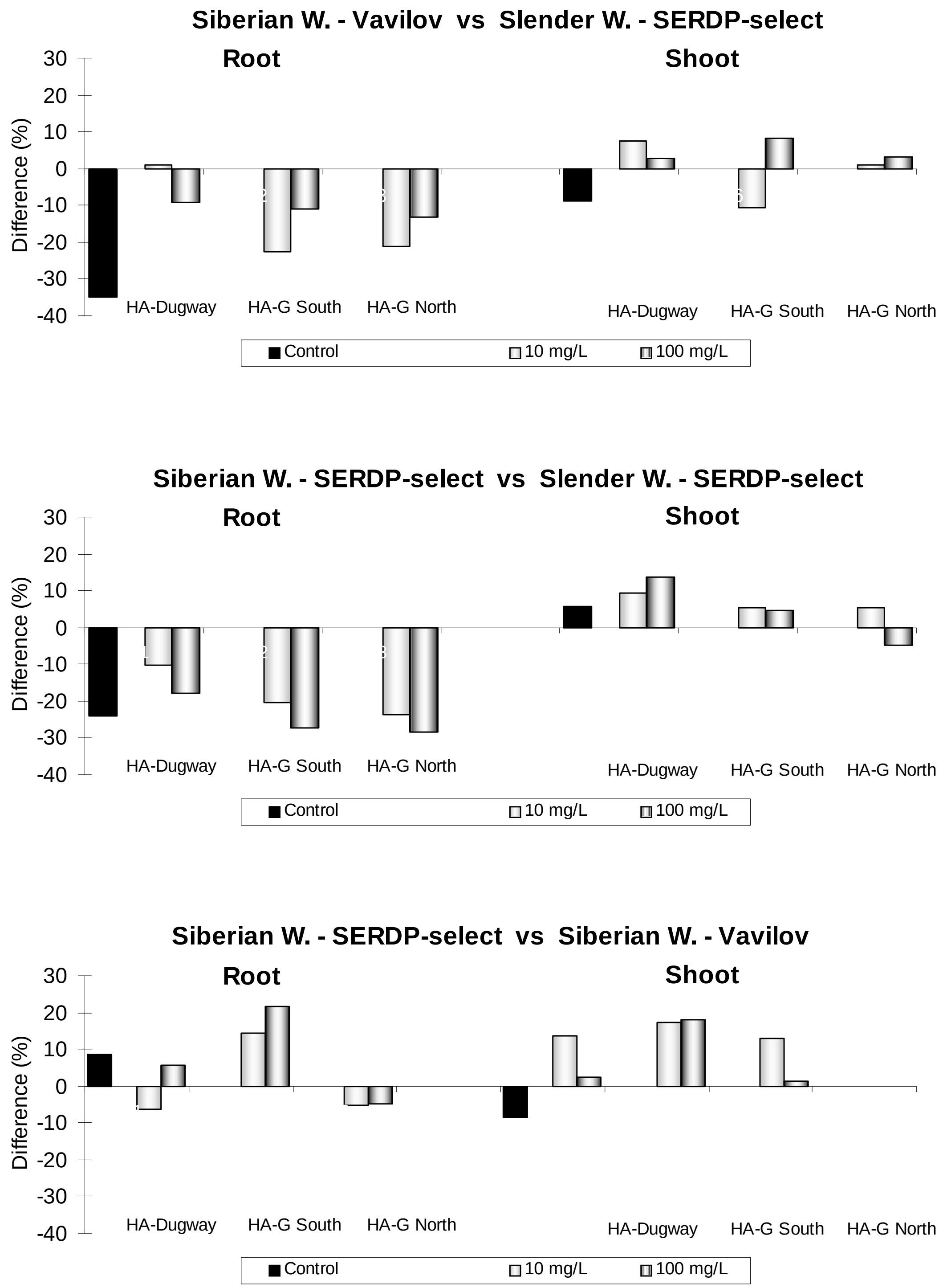

Figure 19. Effect of HAs at different concentrations on the difference (%) of shoot and root lengths between the two varieties grown together for 21-days. Top, COMBI-A, middle, COMBI-B, bottom, COMBI-C.

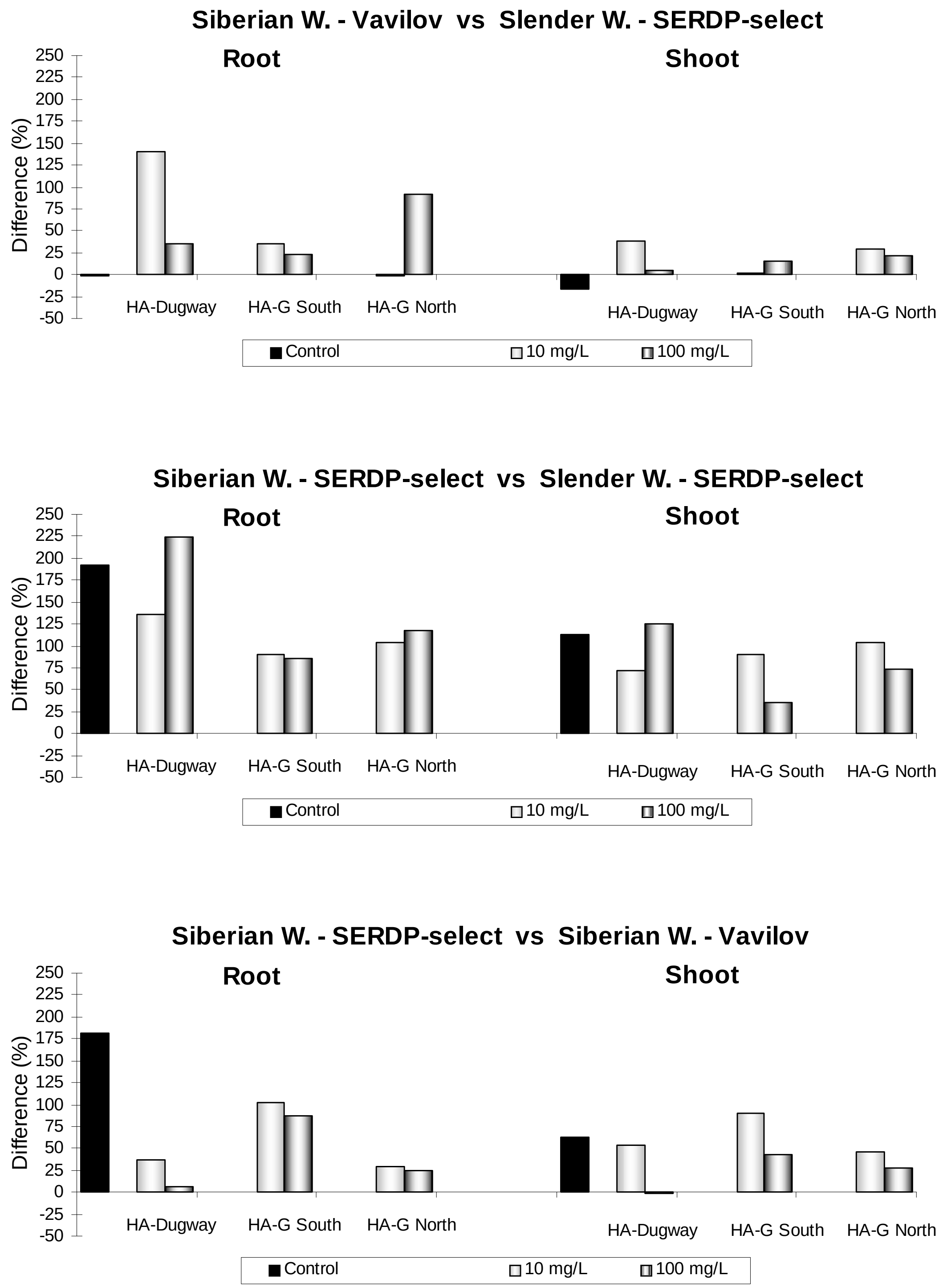

Figure 20. Effect of HAs at different concentrations on the difference (%) of shoot and root fresh weights between the two varieties grown together for 21-days. Top, COMBI-A, middle, COMBI-B, bottom, COMBI-C.

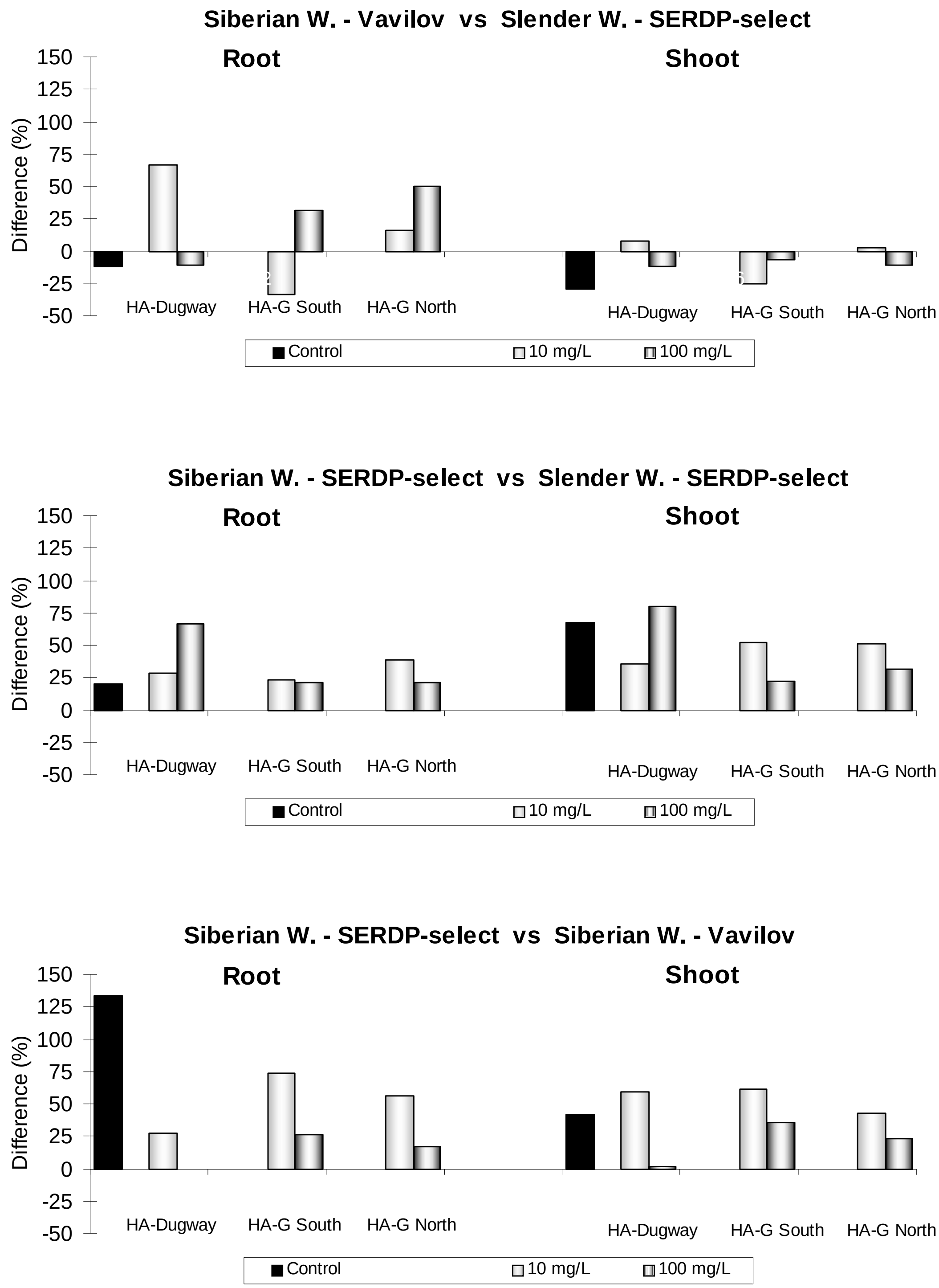

Figure 21. Effect of HAs at different concentrations on the difference (%) of shoot and root dry weights between the two varieties grown together for 21-days. Top, COMBI-A, middle, COMBI-B, bottom, COMBI-C.

Table 1. Elemental composition (on moisture and ash-free basis) of humic acids extracted with 0.5 M NaOH from greenhouse soils where the **cv. Vavilov of Siberian** wheatgrass was grown.

Origin of humic acids	**Moisture** %	**Ash** %	**C** %	**N** %	**H** %	**S** %	**O (*)** %
GN 2A	4.7	1.4	57.2 ± 0.7	5.1 ± 0.1	5.6 ±0.1	1.7 ±0.1	30.4
GN 2B	4.6	1.4	57.0 ± 0.1	4.7 ±0.1	5.5 ±0.1	0.3 ±0.3	32.5
GS 2A	6.5	0.7	57.0 ±0.6	5.0 ±0.1	5.0 ±0.1	0.4 ±0.1	32.6
GS 2B	2.3	1.6	57.0 ±0.2	4.7 ±0.1	5.0 ±0.1	0.4 ±0.1	32.6
D 2A	5.5	0.5	57.6 ±0.9	5.0 ±0.1	5.4 ±0.1	0.3 ±0.1	31.7
D 2B	7.2	2.5	57.4 ±0.6	5.0 ± 0.1	5.4 ±0.1	0.3 ± 0.1	31.7
D 2C	5.2	1.2	56.3 ±0.2	5.2 ±0.1	5.4 ±0.1	0.3 ±0.1	32.8

(*) Oxygen was obtained by difference to 100

Table 2. Atomic ratios (calculated on the basis of data in Table 1) of humic acids extracted with 0.5 M NaOH from greenhouse soils where the **cv. Vavilov of Siberian** wheatgrass was grown.

Origin of humic acids	**C/N**	**C/H**	**O/C**
GN 2A	13.2	0.9	0.4
GN 2B	14.2	0.9	0.4
GS 2A	13.3	0.9	0.4
GS 2B	14.3	0.9	0.4
D 2A	13.4	0.9	0.4
D 2B	13.3	0.9	0.4
D 2C	12.5	0.9	0.4

Table 3. Acidic functional groups content (on moisture and ash-free basis) of humic acids extracted with 0.5 M NaOH from greenhouse soils where the **cv. Vavilov of Siberian** wheatgrass was grown.

Origin of humic acids	**COOH** meq/g	**Phen. OH** meq/g	**Tot. Ac.** meq/g
GN 2A	3.6	0.6	4.2
GN 2B	3.6	0.6	4.2
GS 2A	4.3	2.3	6.6
GS 2B	4.1	2.1	6.2
D 2A	3.9	3.0	6.9
D 2B	3.9	3.0	6.9
D 2C	3.5	3.4	6.9

Table 4. Elemental composition (on moisture and ash-free basis) of humic acids extracted with 0.5 M NaOH from greenhouse soils where the **cv. Pryor of Slender** wheatgrass was grown.

Origin of humic acids	**Moisture** %	**Ash** %	**C** %	**N** %	**H** %	**S** %	**O (*)** %
GN 3A	7.6	0.9	55.6 ±0.9	5.2±0.1	5.1 ±0.2	0.5 ±0.1	33.6
GN 3B	6.9	0.5	56.4 ±0.2	5.2 ±0.1	5.0 ±0.1	0.5 ±0.1	32.9
GS 3A	5.7	1.3	56.5 ±0.5	5.0 ±0.1	5.0 ±0.1	0.4 ±0.1	33.1
GS 3B	5.6	2.7	55.9 ±3.9	4.9 ±0.3	4.9 ±0.4	0.4 ±0.1	33.9
D 3A	7.1	2.6	57.3 ±0.8	5.4 ±0.1	5.5 ±0.2	0.3 ±0.1	31.5
D 3B	4.5	0.4	56.3 ±0.2	5.3 ±0.1	5.4 ±0.1	0.3 ±0.1	32.7
D 3C	5.7	7.9	56.7 ±0.2	5.3 ±0.1	5.1 ±0.1	0.3 ±0.1	32.6

(*) Oxygen was obtained by difference to 100

Table 5. Atomic ratios (calculated on the basis of data in Table 4) of humic acids extracted with 0.5 M NaOH from greenhouse soils where the **cv. Pryor of Slender** wheatgrass was grown.

Origin of humic acids	**C/N**	**C/H**	**O/C**
GN 3A	12.5	0.9	0.5
GN 3B	12.7	0.9	0.4
GS 3A	13.2	0.9	0.4
GS 3B	13.2	1.0	0.5
D 3A	12.4	0.9	0.4
D 3B	12.3	0.9	0.4
D 3C	12.5	0.9	0.4

Table 6. Acidic functional groups content (on moisture and ash-free basis) of humic acids extracted with 0.5 M NaOH from greenhouse soils where the **cv. Pryor of Slender** wheatgrass was grown.

Origin of humic acids	**COOH meq/g**	**Phen. OH meq/g**	**Tot. Ac. meq/g**
GN 3A	3.7	0.7	4.3
GN 3B	3.8	0.5	4.3
GS 3A	3.3	2.6	5.9
GS 3B	3.7	1.7	5.4
D 3A	4.0	1.5	5.5
D 3B	3.8	3.0	6.8
D 3C	4.5	1.8	6.3

Table 7. Elemental composition (on moisture and ash-free basis) of humic acids extracted with 0.5 M NaOH from greenhouse soils where the germplasm line **SERDP-select of Slender** wheatgrass was grown.

Origin of humic acids	Moisture %	Ash %	C %	N %	H %	S %	O (*) %
GN 4A	5.8	1.1	56.2 ±0.7	5.2 ±0.1	5.5 ±0.1	0.4 ±0.1	32.7
GN 4B	4.8	1.4	55.3 ±0.6	5.0 ±0.1	5.2 ±0.1	0.4 ±0.1	34.1
GS 4A	3.5	1.4	57.0 ±0.8	5.0 ±0.1	4.9 ±0.2	0.3 ±0.1	32.8
GS 4B	4.5	1.3	55.4 ±0.3	4.9 ±0.1	4.6 ±0.1	0.3 ±0.1	34.8
GS 4C	5.9	1.7	56.4 ±0.3	4.8 ±0.1	4.7 ±0.2	0.3 ±0.1	33.8
D 4A	4.4	16.1	55.7 ±0.3	5.1 ±0.1	5.3 ±0.1	0.3 ±0.1	33.6
D 4B	3.1	2.0	56.9 ±0.8	5.1 ±0.1	5.4 ±0.2	0.3 ±0.1	32.3
D 4C	5.2	1.8	56.8 ±0.6	5.1 ±0.1	5.0 ±0.1	0.4 ±0.1	32.7

(*) Oxygen was obtained by difference to 100

Table 8. Atomic ratios (calculated on the basis of data in Table 7) of humic acids extracted with 0.5 M NaOH from greenhouse soils where the germplasm line **SERDP-select of Slender** wheatgrass was grown.

Origin of humic acids	C/N	C/H	O/C
GN 4A	12.7	0.8	0.4
GN 4B	12.8	0.9	0.5
GS 4A	13.3	1.0	0.4
GS 4B	13.2	1.0	0.5
GS 4C	13.7	1.0	0.4
D 4A	12.8	0.9	0.5
D 4B	13.0	0.9	0.4
D 4C	13.0	0.9	0.4

Table 9. Acidic functional groups content (on moisture and ash-free basis) of humic acids extracted with 0.5 M NaOH from greenhouse soils where the germplasm line **SERDP-select of Slender** wheatgrass was grown.

Origin of humic acids	COOH meq/g	Phen. OH meq/g	Tot. Ac. meq/g
GN 4A	4.0	0.7	4.7
GN 4B	3.3	2.4	5.8
GS 4A	3.8	1.9	5.7
GS 4B	4.1	1.7	5.7
GS 4C	4.2	0.7	4.9
D 4A	4.2	1.6	5.8
D 4B	3.6	1.2	4.7
D 4C	3.7	1.2	4.8

Table 10. Elemental composition (on moisture and ash-free basis) of humic acids extracted with 0.5 M NaOH from greenhouse soils where the germplasm line **SERDP-select of Siberian** wheatgrass was grown.

Origin of humic acids	Moisture %	Ash %	C %	N %	H %	S %	O (*) %
GN 5A	5.5	7.8	56.9 ±0.2	5.0 ±0.1	5.2 ±0.1	0.4 ±0.1	32.5
GN 5B	3.4	1.1	55.9 ±0.3	4.9 ±0.1	5.1 ±0.2	0.4 ±0.1	33.7
GS 5A	6.4	0.9	56.3 ±0.9	4.9 ±0.1	5.0 ±0.1	0.3 ±0.1	33.5
GS 5B	5.2	0.5	57.6 ±0.9	5.0 ±0.1	5.0 ±0.1	0.3 ±0.1	32.1
D 5A	4.8	2.7	57.3 ±0.3	5.4 ±0.1	5.4 ±0.1	0.3 ±0.1	31.6
D 5B	4.9	1.1	57.5 ±0.5	5.4 ±0.1	5.4 ±0.1	0.3 ±0.1	31.4
D 5C	5.7	2.3	55.8 ±1.3	5.2 ±0.1	5.4 ±0.2	0.4 ±0.1	33.2

(*) Oxygen was obtained by difference to 100

Table 11. Atomic ratios (calculated on the basis of data in Table 10) of humic acids extracted with 0.5 M NaOH from greenhouse soils where the germplasm line **SERDP-select of Siberian** wheatgrass was grown.

Origin of humic acids	C/N	C/H	O/C
GN 5A	13.2	0.9	0.4
GN 5B	13.3	0.9	0.5
GS 5A	13.4	0.9	0.4
GS 5B	13.5	0.9	0.4
D 5A	12.4	0.9	0.4
D 5B	12.4	0.9	0.4
D 5C	12.6	0.9	0.4

Table 12. Acidic functional groups content (on moisture and ash-free basis) of humic extracted with 0.5 M NaOH from greenhouse soils where the germplasm line **SERDP-select of Siberian** wheatgrass was grown.

Origin of humic acids	COOH meq/g	Phen. OH meq/g	Tot. Ac. meq/g
GN 5A	3.8	1.1	4.9
GN 5B	3.5	0.9	4.4
GS 5A	4.0	3.0	7.0
GS 5B	3.8	2.5	6.2
D 5A	3.8	1.6	5.5
D 5B	3.6	2.2	5.9
D 5C	3.8	1.0	4.8

Table 13. Significance level (F value) resulting from one-way Analysis of Variance (ANOVA) of all data obtained for each parameter measured distinctly (except pH) for variety in the combination **SERDP-select Slender and cv. Vavilov Siberian (COMBI-A)**.

Parameter	**SERDP-select Slender**	**cv. Vavilov Siberian**
Germination	0.5 ^{ns}	1.3 ^{ns}
Primary root length	1.57 ^{ns}	2.84 *
Primary shoot length	0.51 ^{ns}	2.47 *
pH	13.38 ***	
Root length	19.41 ***	4.36 **
Shoot length	8.26 ***	6.37 ***
Root fresh weight	3.47 *	0.75 ^{ns}
Shoot fresh weight	9.09 ***	3.35 *
Root dry weight	1.90 ^{ns}	1.32 ^{ns}
Shoot dry weight	8.83 ***	3.63**

*** 0.001; ** 0.01 P; * 0.05 P; ns: nonsignificant

Table 14. Significance level (F value) resulting from one-way Analysis of Variance (ANOVA) of all data obtained for each parameter measured distinctly (except pH) for variety in the combination **SERDP-select Slender and SERDP-select Siberian (COMBI-B)**.

Parameter	**SERDP-select Slender**	**SERDP-select Siberian**
Germination	1.40 ^{ns}	2.4 *
Primary root length	1.34 ^{ns}	4.04 **
Primary shoot length	0.67 ^{ns}	1.08 ^{ns}
pH	20.70 ***	
Root length	0.35 ^{ns}	0.76 ^{ns}
Shoot length	0.87 ^{ns}	1.07 ^{ns}
Root fresh weight	5.93***	0.69 ^{ns}
Shoot fresh weight	15.26 ***	3.64 **
Root dry weight	0.14 ^{ns}	0.66 ^{ns}
Shoot dry weight	9.97 ***	3.87 **

*** 0.001; ** 0.01 P; * 0.05 P; ns: nonsignificant

Table 15. Significance level (F value) resulting from one-way Analysis of Variance (ANOVA) of all data obtained for each parameter measured distinctly (except pH) for variety in the combination **cv. Vavilov Siberian and SERDP-select Siberian (COMBI-C)**.

Parameter	**cv. Vavilov Siberian**	**SERDP-select Siberian**
Germination	1.50 ns	3.70 **
Primary root length	3.43 **	2.43 *
Primary shoot length	0.16 ns	0.69 ns
pH	7.66 ***	
Root length	1.30 ns	1.83 ns
Shoot length	4.53 **	4.62 **
Root fresh weight	8.87 ***	3.16 *
Shoot fresh weight	8.22 ***	5.07 ***
Root dry weight	6.94 ***	3.31 *
Shoot dry weight	7.81 ***	8.24 ***

*** 0.001; ** 0.01 P; * 0.05 P; ns: nonsignificant

Table 16. Effect of HAs at different concentrations on seed germination (expressed as % of germinated seeds) in the combination **SERDP-select Slender and cv. Vavilov Siberian (COMBI-A).**

Treatment	**SERDP-select Slender**		**cv. Vavilov Siberian**	
	(absolute %)	(% of control)	(absolute %)	(% of control)
Control (H_2O)	58 ± 3.3[a]	100.0 ± 5.8[a]	40 ± 2.8	100.0 ± 7.1
D HA				
10 mg/L	64 ± 6.1	110.3 ± 10.5	48 ± 6.6	120.0 ± 16.4
100 mg/L	64 ± 3.6	110.3 ± 6.2	28 ± 6.6	70.0 ± 16.4
GS HA				
10 mg/L	70 ± 7.5	120.7 ± 12.9	48 ± 6.6	120.0 ± 16.4
100 mg/L	68 ± 5.2	117.2 ± 9.0	44 ± 4.6	110.0 ± 11.4
GN HA				
10 mg/L	64 ± 6.7	110.3 ± 10.5	50 ± 7.5	125.0 ± 18.7
100 mg/L	70 ± 4.0	120.7 ± 6.9	34 ± 8.8	85.0 ± 21.9

[a] standard error (n=5)

Table 17. Effect of HAs at different concentrations on seed germination (expressed as % of germinated seeds) in the combination **SERDP-select Slender and SERDP-select Siberian (COMBI-B)**.

Treatment	**SERDP-select Slender**		**SERDP-select Siberian**		
	(absolute %)	(% of control)	(absolute %)	(% of control)	
Control (H_2O)	54 ± 8.3[a]	100.0 ± 15.4[a]	44 ± 4.6	100.0 ± 10.4	
D HA					
10 mg/L	52 ± 5.9	96.3 ± 11.0	56 ± 2.2	127.3 ± 5.0	
100 mg/L	44 ± 6.1	81.5 ± 11.2	44 ± 4.6	100.0 ± 10.4	
GS HA					
10 mg/L	64 ± 4.6	118.5 ± 8.4	60 ± 4.0	136.4 ± 9.1	*
100 mg/L	34 ± 8.3	63.0 ± 15.4	44 ± 4.6	100.0 ± 10.4	
GN HA					
10 mg/L	52 ± 5.9	96.3 ± 11.0	46 ± 4.6	104.5 ± 10.4	
100 mg/L	46 ± 9.6	85.2 ± 17.8	42 ± 3.3	95.5 ± 7.6	

[a] standard error (n=5)
* $P \leq 0.05$, according to the LSD test.

Table 18. Effect of HAs at different concentrations on seed germination (expressed as % of germinated seeds) in the combination **cv. Vavilov Siberian and SERDP-select Siberian (COMBI-C)**.

Treatment	cv. Vavilov Siberian		SERDP-select Siberian		
	(absolute %)	(% of control)	(absolute %)	(% of control)	
Control (H_2O)	56 ± 6.1[a]	100.0 ± 10.8[a]	34 ± 4.6	100.0 ± 13.4	
D HA					
10 mg/L	42 ± 5.2	75.0 ± 9.3	44 ± 4.6	129.4 ± 13.4	
100 mg/L	38 ± 5.9	67.9 ± 10.6	60 ± 2.8	176.5 ± 8.3	**
GS HA					
10 mg/L	46 ± 5.4	82.1 ± 9.6	58 ± 5.9	170.6 ± 17.4	**
100 mg/L	36 ± 2.2	64.3 ± 3.9	52 ± 4.4	152.9 ± 12.9	*
GN HA					
10 mg/L	38 ± 5.2	67.9 ± 9.3	40 ± 4.0	117.6 ± 11.8	
100 mg/L	46 ± 3.6	82.1 ± 6.4	50 ± 4.0	147.1 ± 11.8	*

[a] standard error (n=5)
** $P \leq 0.01$; * $P \leq 0.05$, according to the LSD test.

Table 19. Effect of HAs at different concentrations on the length of primary root and shoot of germinated seeds in the combination **SERDP-select Slender and cv. Vavilov Siberian (COMBI-A)**.

Treatment	**SERDP-select Slender**				**cv. Vavilov Siberian**			
	Root		**Shoot**		**Root**		**Shoot**	
	(cm)	(%)	(cm)	(%)	(cm)	(%)	(cm)	(%)
Control (H_2O)	1.8 ± 0.1[a]	100.0 ± 3.7[a]	1.3 ± 0.0	100.0 ± 3.1	1.9 ± 0.0	100.0 ± 2.9	1.4 ± 0.1	100.0 ± 8.5
D HA								
10 mg/L	1.8 ± 0.1	101.7 ± 2.8	1.4 ± 0.2	109.4 ± 12.0	1.9 ± 0.2	101.5 ± 13.3	1.3 ± 0.2	94.2 ± 13.4
100 mg/L	1.8 ± 0.1	98.9 ± 6.3	1.2 ± 0.1	95.6 ± 11.9	2.8 ± 0.2	148.7 ± 9.3 *	2.3 ± 0.3	162.2 ± 19.5 *
GS HA								
10 mg/L	1.8 ± 0.1	98.9 ± 8.1	1.3 ± 0.1	99.7 ± 1.2	2.2 ± 0.1	118.4 ± 6.6	1.4 ± 0.2	96.0 ± 13.6
100 mg/L	2.1 ± 0.1	117.5 ± 5.1	1.3 ± 0.1	96.3 ± 5.5	2.3 ± 0.1	121.6 ± 6.0	1.7 ± 0.2	121.5 ± 12.6
GN HA								
10 mg/L	1.8 ± 0.1	97.0 ± 6.4	1.4 ± 0.1	106.5 ± 7.5	2.1 ± 0.2	110.0 ± 10.9	1.6 ± 0.1	115.8 ± 9.7
100 mg/L	2.1 ± 0.1	113.7 ± 6.7	1.5 ± 0.2	116.1 ± 12.4	2.0 ± 0.2	108.0 ± 8.9	1.5 ± 0.2	103.8 ± 14.7

[a] standard error (n=5)
* $P \leq 0.05$, according to the LSD test.

Table 20. Effect of HAs at different concentrations on the length of primary root and shoot of germinated seeds in the combination **SERDP-select Slender and SERDP-select Siberian (COMBI-B).**

Treatment	**SERDP-select Slender**				**SERDP-select Siberian**				
	Root		**Shoot**		**Root**			**Shoot**	
	(cm)	(%)	(cm)	(%)	(cm)	(%)		(cm)	(%)
Control (H_2O)	2.1 ± 0.2[a]	100.0 ± 7.5[a]	1.4 ± 0.1	100.0 ± 10.3	1.5 ± 0.2	100.0 ± 10.3		1.5 ± 0.2	100.0 ± 15.6
D HA									
10 mg/L	2.1 ± 0.2	99.9 ± 9.2	1.4 ± 0.2	99.0 ± 12.1	2.3 ± 0.2	147.8 ±10.7	**	1.5 ± 0.1	100.2 ± 10.0
100 mg/L	1.9 ± 0.1	90.5 ± 5.5	1.5 ± 0.1	103.8 ± 8.0	2.2 ± 0.2	146.9 ± 15.0	**	1.8 ± 0.1	116.4 ± 9.5
GS HA									
10 mg/L	1.7 ± 0.0	80.4 ± 1.9	1.2 ± 0.1	80.9 ± 5.8	2.3 ± 0.1	150.2 ± 8.8	**	1.9 ± 0.1	126.8 ± 10.2
100 mg/L	2.0 ± 0.2	96.3 ± 10.6	1.5 ± 0.2	105.3 ± 12.4	2.1 ± 0.1	140.4 ± 8.7	*	1.8 ± 0.3	119.1 ± 19.5
GN HA									
10 mg/L	1.6 ± 0.2	77.9 ± 8.5	1.2 ± 0.2	83.6 ± 11.7	2.4 ± 0.1	157.9 ± 6.8	**	1.8 ± 0.2	117.1 ± 12.5
100 mg/L	1.7 ± 0.1	79.8 ± 6.7	1.4 ± 0.2	99.5 ± 12.5	1.6 ± 0.2	102.6 ± 11.4		1.3 ± 0.1	83.2 ± 10.2

[a] standard error (n=5)
** $P \leq 0.01$; * $P \leq 0.05$, according to the LSD test.

Table 21. Effect of HAs at different concentrations on the length of primary root and shoot of germinated seeds in the combination **cv. Vavilov Siberian and SERDP-select Siberian (COMBI-C)**.

Treatment	cv. Vavilov Siberian					SERDP-select Siberian				
	Root			Shoot		Root			Shoot	
	(cm)	(%)		(cm)	(%)	(cm)	(%)		(cm)	(%)
Control (H_2O)	1.5 ± 0.1[a]	100.0 ± 6.1[a]		1.7 ± 0.1	100.0 ± 4.9	1.5 ± 0.1	100.0 ± 9.0		2.1 ± 0.2	100.0 ± 9.7
D HA										
10 mg/L	2.3 ± 0.1	146.3 ± 6.5	**	1.6 ± 0.1	95.5 ± 5.0	2.0 ± 0.2	132.8 ± 11.6	*	1.7 ± 0.2	82.5 ± 10.0
100 mg/L	2.0 ± 0.1	127.3 ± 8.1	*	1.6 ± 0.3	95.0 ± 16.5	2.2 ± 0.1	151.1 ± 7.9	*	1.7 ± 0.2	82.1 ± 9.6
GS HA										
10 mg/L	1.9 ± 0.1	125.6 ± 7.0	*	1.5 ± 0.1	88.2 ± 7.2	2.0 ± 0.1	135.2 ± 7.1	*	1.8 ± 0.2	84.0 ± 11.4
100 mg/L	2.2 ± 0.1	139.7 ± 6.7	**	1.6 ± 0.1	91.4 ± 8.4	2.0 ± 0.1	130.9 ± 9.3	*	1.5 ± 0.1	70.7 ± 4.3
GN HA										
10 mg/L	1.9 ± 0.1	123.7 ± 7.9	*	1.5 ± 0.2	86.8 ± 13.4	1.7 ± 0.2	115.3 ± 10.6		1.7 ± 0.3	79.6 ± 14.5
100 mg/L	2.1 ± 0.1	136.0 ± 8.0	**	1.7 ± 0.2	97.4 ± 14.8	2.0 ± 0.1	133.6 ± 9.1	*	1.5 ± 0.2	72.2 ± 10.6

[a] standard error (n=5)
** P ≤ 0.01; * P ≤ 0.05, according to the LSD test.

Table 22. Effect of HAs at different concentrations on the pH value of growth medium measured after 21-day seedling growth in the three combinations.

Treatment	**SERDP-select Slender and cv. Vavilov Siberian**	**SERDP-select Slender and SERDP-select Siberian**	**cv. Vavilov Siberian and SERDP- select Siberian**
Control (H_2O)	4.1 ± 0.1[a]	5.7 ± 0.1	6.1 ± 0.0
D HA			
10 mg/L	5.1 ± 0.1 ***	5.6 ± 0.1	5.4 ± 0.1**
100 mg/L	4.2 ± 0.1	4.2 ± 0.3 ***	5.2 ± 0.2 ***
GS HA			
10 mg/L	4.8 ± 0.1 ***	5.3 ± 0.1	5.4 ± 0.1 **
100 mg/L	4.1 ± 0.1	4.0 ± 0.1 ***	4.8 ± 0.2 ***
GN HA			
10 mg/L	4.6 ± 0.2 **	5.7 ± 0.1	5.7 ± 0.1
100 mg/L	4.2 ± 0.1	4.4 ± 0.2 ***	4.8 ± 0.2 ***

[a] standard error (n=5)

*** $P \leq 0.001$; ** $P \leq 0.01$; * $P \leq 0.05$, according to the LSD test.

Table 23. Effect of HAs at different concentrations on the length of shoots and roots measured after 21-day growth in the combination **SERDP-select Slender and cv. Vavilov Siberian (COMBI-A)**.

Treatment	**SERDP-select Slender**						**cv. Vavilov Siberian**					
	Root			**Shoot**			**Root**			**Shoot**		
	(cm)	(%)		(cm)	(%)		(cm)	(%)		(cm)	(%)	
Control (H_2O)	24.2 ± 1.2[a]	100.0 ± 8.1[a]		4.5 ± 0.2	100.0 ± 7.9		15.7 ± 1.0	100.0 ± 10.0		4.1 ± 0.2	100.0 ± 6.6	
D HA												
10 mg/L	11.8 ± 0.6	48.8 ± 2.4	***	3.4 ± 0.2	75.2 ± 3.5	***	11.9 ± 0.7	75.8 ± 4.6		3.6 ± 0.2	88.6 ± 4.5	
100 mg/L	17.1 ± 0.7	70.8 ± 2.7	***	4.6 ± 0.1	103.0 ± 2.2		15.5 ± 1.0	98.7 ± 6.2		4.8 ± 0.1	116.3 ± 3.2	
GS HA												
10 mg/L	13.3 ± 0.4	55.0 ± 1.5	***	3.5 ± 0.2	77.8 ± 4.2	***	10.3 ± 1.0	65.5 ± 6.3	**	3.1 ± 0.1	76.4 ± 1.8	**
100 mg/L	18.3 ± 0.2	75.8 ± 0.6	***	4.4 ± 0.2	97.8 ± 2.0		16.3 ± 1.0	103.6 ± 6.6		4.8 ± 0.3	116.3 ± 7.0	
GN HA												
10 mg/L	12.0 ± 0.4	49.8 ± 1.8	***	3.3 ± 0.2	74.1 ± 3.9	***	9.5 ± 1.1	60.4 ± 7.1	**	3.4 ± 0.2	82.1 ± 3.9	*
100 mg/L	17.7 ± 1.7	73.2 ± 7.1	***	4.0 ± 0.2	89.3 ± 5.1		15.4 ± 2.2	97.7 ± 13.9		4.2 ± 0.4	101.2 ± 10.1	

[a] standard error (n=5)
*** P ≤ 0.001; ** P ≤ 0.01; * P ≤ 0.05, according to the LSD test.

Table 24. Effect of HAs at different concentrations on the length of shoots and roots measured after 21-day growth in the combination **SERDP-select Slender and SERDP-select Siberian (COMBI-B).**

Treatment	**SERDP-select Slender**				**SERDP-select Siberian**			
	Root		**Shoot**		**Root**		**Shoot**	
	(cm)	(%)	(cm)	(%)	(cm)	(%)	(cm)	(%)
Control (H_2O)	19.2 ± 0.8[a]	100.0 ± 6.8[a]	4.4 ± 0.4	100.0 ± 13.2	14.6 ± 0.8	100.0 ± 8.8	4.7 ± 0.3	100.0 ± 11.7
D HA								
10 mg/L	18.8 ± 0.6	97.7 ± 3.1	4.4 ± 0.2	99.2 ± 4.9	16.9 ± 0.8	115.8 ± 5.4	4.8 ± 0.4	102.8 ± 7.6
100 mg/L	19.4 ± 0.9	101.0 ± 4.7	4.9 ± 0.2	109.8 ± 5.6	16.0 ± 1.3	109.6 ± 9.1	5.5 ± 0.2	118.1 ± 3.9
GS HA								
10 mg/L	19.8 ± 0.7	103.2 ± 3.9	4.7 ± 0.2	105.6 ± 4.5	15.8 ± 0.7	108.5 ± 4.7	4.9 ± 0.2	105.3 ± 3.6
100 mg/L	19.8 ± 1.0	103.1 ± 5.1	5.1 ± 0.3	115.8 ± 6.1	14.4 ± 1.0	98.9 ± 6.8	5.4 ± 0.4	114.6 ± 9.3
GN HA								
10 mg/L	20.0 ± 1.0	104.3 ± 5.3	4.6 ± 0.2	103.4 ± 5.0	15.3 ± 0.6	105.0 ± 4.2	4.8 ± 0.3	103.2 ± 7.1
100 mg/L	20.6 ± 1.1	107.3 ± 5.8	4.8 ± 0.1	108.3 ± 3.1	14.8 ± 1.0	101.4 ± 6.6	4.6 ± 0.2	97.5 ± 5.1

[a] standard error (n=5)

Table 25. Effect of HAs at different concentrations on the length of shoots and roots measured after 21-day growth in the combination **cv. Vavilov Siberian and SERDP-select Siberian (COMBI-C)**.

Treatment	**cv. Vavilov Siberian**					**SERDP-select Siberian**				
	Root		**Shoot**			**Root**		**Shoot**		
	(cm)	(%)	(cm)	(%)		(cm)	(%)	(cm)	(%)	
Control (H_2O)	15.1 ± 1.5[a]	100.0 ± 15.3[a]	4.2 ± 0.2	100.0 ± 9.3		16.4 ± 1.2	100.0 ± 11.5	3.8 ± 0.1	100.0 ± 5.4	
D HA										
10 mg/L	16.5 ± 0.8	109.6 ± 5.3	4.9 ± 0.2	117.6 ± 4.0	*	15.5 ± 0.8	94.7 ± 5.1	5.6 ± 0.3	146.2 ± 8.3	**
100 mg/L	15.5 ± 0.8	102.5 ± 5.3	5.2 ± 0.1	125.6 ± 1.8	**	16.3 ± 0.5	99.7 ± 3.4	5.4 ± 0.3	140.8 ± 7.2	**
GS HA										
10 mg/L	16.3 ± 0.6	108.1 ± 3.9	4.4 ± 0.2	104.4 ± 3.8		18.7 ± 0.8	113.9 ± 4.9	5.1 ± 0.3	133.8 ± 7.5	**
100 mg/L	13.3 ± 0.8	88.4 ± 5.1	5.0 ± 0.2	120.0 ± 5.9	*	16.2 ± 1.0	99.1 ± 5.9	5.9 ± 0.1	154.8 ± 3.6	**
GN HA										
10 mg/L	16.9 ± 1.0	112.3 ± 6.5	4.2 ± 0.3	99.6 ± 6.2		16.1 ± 1.3	98.1 ± 7.7	4.7 ± 0.3	122.8 ± 9.2	
100 mg/L	14.7 ± 1.2	97.7 ± 7.7	5.3 ± 0.2	126.4 ± 5.5	**	14.0 ± 0.4	85.7 ± 2.4	5.3 ± 0.4	139.9 ± 10.2	**

[a] standard error (n=5)

** P ≤ 0.01; * P ≤ 0.05, according to the LSD test.

Table 26. Effect of HAs at different concentrations on the fresh weight of shoots and roots measured after 21-day growth in the combination **SERDP-select Slender and cv. Vavilov Siberian (COMBI-A)**.

Treatment	**SERDP-select Slender**						**cv. Vavilov Siberian**				
	Root			**Shoot**			**Root**		**Shoot**		
	(mg)	(%)		(mg)	(%)		(mg)	(%)	(mg)	(%)	
Control (H_2O)	27.3 ± 3.1[a]	100.0 ± 11.4[a]		65.6 ± 9.0	100.0 ± 13.8		26.9 ± 2.3	100.0 ± 8.5	55.0 ± 7.7	100.0 ± 13.9	
D HA											
10 mg/L	11.7 ± 2.9	42.8 ± 10.8	*	21.3 ± 1.2	32.5 ± 1.8	***	28.2 ± 6.3	104.7 ± 23.2	29.5 ± 6.5	53.5 ± 11.9	*
100 mg/L	21.2 ± 2.9	77.7 ± 10.6		55.6 ± 3.1	84.7 ± 4.7		28.6 ± 5.0	106.2 ± 18.5	58.5 ± 3.8	106.3 ± 7.0	
GS HA											
10 mg/L	17.7 ± 3.3	64.8 ± 12.2	*	26.1 ± 2.8	39.8 ± 4.3	***	23.9 ± 5.0	88.7 ± 18.5	26.4 ± 4.1	47.9 ± 7.5	*
100 mg/L	25.7 ± 2.0	94.2 ± 7.2		51.4 ± 2.7	78.4 ± 4.2		31.8 ± 5.2	118.1 ± 19.2	59.2 ± 10.7	107.6 ± 19.4	
GN HA											
10 mg/L	17.9 ± 3.0	65.7 ± 10.9	*	26.3 ± 4.4	40.1 ± 6.7	***	17.7 ± 2.3	65.7 ± 8.7	34.0 ± 2.3	61.7 ± 4.2	*
100 mg/L	14.8 ± 1.0	54.3 ± 3.4	*	39.8 ± 7.2	60.7 ± 11.0	**	28.3 ± 5.1	105.1 ± 19.0	48.6 ± 9.1	88.3 ± 16.6	

[a] standard error (n=5)
*** $P \leq 0.001$; ** $P \leq 0.01$; * $P \leq 0.05$, according to the LSD test.

Table 27. Effect of HAs at different concentrations on the fresh weight of shoots and roots measured after 21-day growth in the combination **SERDP-select Slender and SERDP-select Siberian (COMBI-B)**.

Treatment	**SERDP-select Slender**						**SERDP-select Siberian**					
	Root			**Shoot**			**Root**			**Shoot**		
	(mg)	(%)		(mg)	(%)		(mg)	(%)		(mg)	(%)	
Control (H_2O)	14.6 ± 2.6[a]	100.0 ± 17.7[a]		37.0 ± 3.8	100.0 ± 10.3		42.8 ± 7.0	100.0 ± 16.3		78.5 ± 9.3	100.0 ± 11.8	
D HA												
10 mg/L	21.1 ± 0.5	144.6 ± 3.7	*	41.9 ± 1.8	113.3 ± 4.9		49.9 ± 3.0	116.7 ± 7.0		72.2 ± 7.1	92.0 ± 9.0	
100 mg/L	17.2 ± 1.0	117.5 ± 7.0		60.0 ± 7.9	162.2 ± 21.2	**	55.5 ± 6.3	129.8 ± 14.7		135.0 ± 14.7	171.9 ± 18.7	**
GS HA												
10 mg/L	22.3 ± 1.2	152.7 ± 8.0	**	53.5 ± 5.8	144.8 ± 15.7	*	42.5 ± 3.9	99.5 ± 9.2		102.1 ± 14.6	130.0 ± 18.6	
100 mg/L	27.8 ± 1.4	190.2 ± 9.3	***	96.5 ± 0.0	260.9 ± 0.0	***	51.5 ± 7.3	120.5 ± 17.0		131.1 ± 10.5	166.9 ± 13.3	**
GN HA												
10 mg/L	20.6 ± 2.2	140.7 ± 14.8	*	41.5 ± 6.5	112.3 ± 17.5		41.8 ± 3.4	97.7 ± 8.0		84.3 ± 12.0	107.4 ± 15.3	
100 mg/L	19.9 ± 0.5	136.5 ± 3.8	*	69.4 ± 1.9	187.6 ± 5.2	***	43.3 ± 8.2	101.2 ± 19.1		120.6 ± 14.5	153.6 ± 18.4	*

[a] standard error (n=5)

*** P ≤ 0.001; ** P ≤ 0.01; * P ≤ 0.05, according to the LSD test.

Table 28. Effect of HAs at different concentrations on the fresh weight of shoots and roots measured after 21-day growth in the combination **cv. Vavilov Siberian and SERDP-select Siberian (COMBI-C)**.

Treatment	cv. Vavilov Siberian						SERDP-select Siberian					
	Root			Shoot			Root			Shoot		
	(mg)	(%)		(mg)	(%)		(mg)	(%)		(mg)	(%)	
Control (H_2O)	13.9 ± 3.1[a]	100.0 ± 22.3[a]		40.4 ± 4.6	100.0 ± 11.4		39.1 ± 7.9	100.0 ± 20.2		65.9 ± 12.2	100.0 ± 18.5	
D HA												
10 mg/L	34.3 ± 0.3	246.5 ± 2.2	***	88.5 ± 0.0	219.0 ± 0.0	***	47.0 ± 6.3	120.0 ± 16.0		135.7 ± 7.2	205.8 ± 10.9	***
100 mg/L	26.0 ± 3.5	187.0 ± 25.2	**	75.5 ± 0.0	187.3 ± 0.0	**	27.6 ± 2.9	70.6 ± 7.5		75.6 ± 9.1	114.6 ± 13.8	
GS HA												
10 mg/L	30.4 ± 2.9	218.1 ± 20.9	***	48.6 ± 4.2	120.3 ± 10.4		61.3 ± 0.0	156.6 ± 0.0	*	92.6 ± 7.8	140.4 ± 11.8	
100 mg/L	21.9 ± 1.4	156.9 ± 10.0	*	76.3 ± 7.4	188.7 ± 18.3	**	40.8 ± 7.5	104.4 ± 19.1		109.1 ± 9.4	165.5 ± 14.2	**
GN HA												
10 mg/L	39.1 ± 2.8	280.8 ± 20.1	***	59.9 ± 12.7	148.3 ± 31.4	*	50.7 ± 4.2	129.6 ± 10.7		87.1 ± 12.3	132.1 ± 18.7	
100 mg/L	27.9 ± 1.6	200.3 ± 11.6	**	93.8 ± 4.4	232.3 ± 10.9	***	34.6 ± 5.8	88.4 ± 14.8		119.1 ± 9.7	180.7 ± 14.7	**

[a] standard error (n=5)

*** $P \leq 0.001$; ** $P \leq 0.01$; * $P \leq 0.05$, according to the LSD test.

Table 29. Effect of HAs at different concentrations on the dry weight of shoots and roots measured after 21-day growth in the combination **SERDP-select Slender and cv. Vavilov Siberian (COMBI-A)**.

Treatment	**SERDP-select Slender**					**cv. Vavilov Siberian**				
	Root		**Shoot**			**Root**		**Shoot**		
	(mg)	(%)	(mg)	(%)		(mg)	(%)	(mg)	(%)	
Control (H_2O)	2.4 ± 0.3[a]	100.0 ± 11.8[a]	11.4 ± 1.5	100.0 ± 13.5		2.1 ± 0.3	100.0 ± 12.1	8.0 ± 1.1	100.0 ± 13.7	
D HA										
10 mg/L	1.3 ± 0.3	53.4 ± 13.8	4.2 ± 0.3	36.6 ± 2.3	***	2.2 ± 0.3	101.7 ± 13.8	4.5 ± 1.1	55.6 ± 13.6	*
100 mg/L	2.4 ± 0.3	100.3 ± 10.5	9.9 ± 0.6	86.5 ± 4.8		2.2 ± 0.1	101.7 ± 5.8	8.7 ± 0.7	108.3 ± 8.9	
GS HA										
10 mg/L	2.1 ± 0.3	88.7 ± 13.8	5.3 ± 0.9	46.3 ± 8.1	***	1.4 ± 0.2	67.0 ± 8.2	4.0 ± 0.5	49.1 ± 6.1	**
100 mg/L	2.0 ± 0.2	81.5 ± 8.5	8.9 ± 0.4	77.9 ± 3.5		2.6 ± 0.4	122.1 ± 19.4	8.3 ± 1.4	102.7 ± 17.0	
GN HA										
10 mg/L	1.9 ± 0.4	77.1 ± 17.3	4.7 ± 0.6	41.0 ± 5.3	***	2.2 ± 0.1	101.7 ± 5.1	4.8 ± 0.3	59.4 ± 4.3	*
100 mg/L	1.4 ± 0.2	57.0 ± 6.6	7.7 ± 0.9	67.7 ± 8.0	**	2.1 ± 0.4	97.6 ± 16.8	6.9 ± 1.0	85.2 ± 12.5	

[a] standard error (n=5)
*** P ≤ 0.001; ** P ≤ 0.01; * P ≤ 0.05, according to the LSD test.

Table 30. Effect of HAs at different concentrations on the dry weight of shoots and roots measured after 21-day growth in the combination **SERDP-select Slender and SERDP-select Siberian (COMBI-B)**.

Treatment	**SERDP-select Slender**					SERDP-select Siberian				
	Root		**Shoot**			**Root**		**Shoot**		
	(mg)	(%)	(mg)	(%)		(mg)	(%)	(mg)	(%)	
Control (H_2O)	2.2 ± 0.2[a]	100.0 ± 8.0[a]	6.3 ± 1.2	100.0 ± 19.0		2.6 ± 0.3	100.0 ± 10.1	10.6 ± 2.2	100.0 ± 21.0	
D HA										
10 mg/L	2.1 ± 0.3	96.3 ± 13.2	7.4 ± 0.4	118.1 ± 6.3		2.7 ± 0.1	103.2 ± 5.3	10.1 ± 0.8	95.9 ± 7.1	
100 mg/L	2.0 ± 0.2	93.0 ± 11.2	10.3 ± 1.2	163.6 ± 19.6	**	3.4 ± 0.5	129.5 ± 18.9	18.6 ± 1.8	176.1 ± 17.1	**
GS HA										
10 mg/L	2.0 ± 0.3	93.6 ± 14.2	9.0 ± 0.9	143.1 ± 13.4	*	2.5 ± 0.2	96.6 ± 8.1	13.8 ± 2.1	130.2 ± 19.4	
100 mg/L	2.3 ± 0.3	105.8 ± 15.3	14.9 ± 0.0	235.8 ± 0.0	***	2.8 ± 0.5	107.3 ± 17.1	18.1 ± 0.0	171.5 ± 0.0	**
GN HA										
10 mg/L	2.0 ± 0.2	91.0 ± 8.4	7.5 ± 1.1	118.8 ± 17.4		2.7 ± 0.2	105.2 ± 8.1	11.3 ± 1.6	107.2 ± 14.7	
100 mg/L	2.1 ± 0.3	96.9 ± 11.4	12.3 ± 0.4	194.5 ± 6.5	***	2.6 ± 0.3	98.5 ± 12.0	16.1 ± 1.8	152.5 ± 16.6	*

[a] standard error (n=5)

*** P ≤ 0.001; ** P ≤ 0.01; * P ≤ 0.05, according to the LSD test.

Table 31. Effect of HAs at different concentrations on the dry weight of shoots and roots measured after 21-day growth in the combination **cv. Vavilov Siberian and SERDP-select Siberian (COMBI-C)**.

Treatment	**cv. Vavilov Siberian**						**SERDP-select Siberian**					
	Root			**Shoot**			**Root**			**Shoot**		
	(mg)	(%)		(mg)	(%)		(mg)	(%)		(mg)	(%)	
Control (H_2O)	1.3 ± 0.2[a]	100.0 ± 16.7[a]		6.2 ± 0.7	100.0 ± 10.5		3.1 ± 0.3	100.0 ± 9.9		8.8 ± 1.2	100.0 ± 14.0	
D HA												
10 mg/L	2.6 ± 0.2	197.0 ± 12.0	***	13.3 ± 0.0	212.6 ± 0.0	***	3.3 ± 0.4	107.8 ± 12.4		21.1 ± 1.5	238.7 ± 17.3	***
100 mg/L	2.0 ± 0.2	152.8 ± 16.8	*	10.5 ± 1.8	168.0 ± 0.0	**	2.0 ± 0.3	65.0 ± 8.8		10.7 ± 1.2	120.7 ± 13.4	
GS HA												
10 mg/L	2.1 ± 0.1	160.4 ± 9.6	**	7.9 ± 0.8	126.6 ± 12.7		2.7 ± 0.6	119.4 ± 20.4		12.7 ± 1.0	143.9 ± 11.4	
100 mg/L	2.0 ± 0.1	151.0 ± 9.5	*	10.9 ± 1.0	174.3 ± 16.3	**	2.5 ± 0.3	81.9 ± 8.0		14.7 ± 1.1	166.0 ± 12.9	**
GN HA												
10 mg/L	2.9 ± 0.1	217.8 ± 5.3	***	9.0 ± 1.7	144.9 ± 26.4	*	4.5 ± 0.6	146.2 ± 20.0	*	12.9 ± 1.8	145.9 ± 20.1	*
100 mg/L	2.0 ± 0.2	153.8 ± 14.9	*	13.6 ± 0.6	217.4 ± 10.2	***	2.4 ± 0.3	77.1 ± 10.2		16.7 ± 0.6	188.3 ± 7.1	***

[a] standard error (n=5)

*** $P \leq 0.001$; ** $P \leq 0.01$; * $P \leq 0.05$, according to the LSD test.